DOCUMENT RESUME

ED 410 414 CE 074 576

AUTHOR Joerschke, John D.
TITLE Exploring Technology Education: Exploring Manufacturing Technology.
INSTITUTION Multistate Academic and Vocational Curriculum Consortium, Stillwater, OK.
PUB DATE 1997-00-00
NOTE 134p.; For related documents, see CE 074 574-575.
AVAILABLE FROM Multistate Academic and Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074; telephone: 800/654-3988; World Wide Web: http://www.mavcc.org (teacher edition, order no. 301501: $11.50; student edition, order no. 301502: $10, 6 or more student editions: $5 each).
PUB TYPE Guides - Classroom - Learner (051) -- Guides - Classroom - Teacher (052)
EDRS PRICE EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Career Education; *Career Exploration; Career Guidance; Critical Thinking; Industry; Laboratory Procedures; Laboratory Safety; *Learning Activities; Lesson Plans; *Manufacturing; Postsecondary Education; *Production Techniques; Productivity; Secondary Education; Teaching Guides; Teaching Methods; Technological Advancement; *Technology Education; Thinking Skills; Units of Study; Vocational Education

ABSTRACT

These instructional materials include a teacher's guide designed to assist instructors in organizing and presenting a unit of study on manufacturing technology and a student guide. The materials are based on the curriculum-alignment concept of first stating the objectives, developing instructional strategies for teaching those objectives, and then evaluating based on the objectives. Topics covered in the teacher materials include the following: using Agency for Instructional Technology (AIT) media programs; attachment-point construction; and forming, casting, and conditioning a paperweight casting. The teacher edition includes the following: suggested activities, learning activities sheet, optional assignment sheets, answers to assignment sheets, teacher supplements, written test, answers to written test, and unit evaluation form. In addition, the teacher edition includes a section on use of the publication, a competency profile, instructional and task analyses, academic and workplace skill classifications and definitions, and a related academic and workplace skills list. Topics covered in the student materials are as follows: manufacturing careers, materials and processes used to produce a manufactured produce, elements of the methods used to process the basic industrial materials, planning a production process, evaluating a production process, fabricating and testing composite materials, composite materials used in airframe manufacturing, and wing-spar pattern. The student edition includes the following components of a unit of instruction: objective sheet, information sheet, assignment sheets, lab activity sheets, and student supplements. (KC)

ED 410 414

Exploring Technology Education
Exploring Manufacturing Technology

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

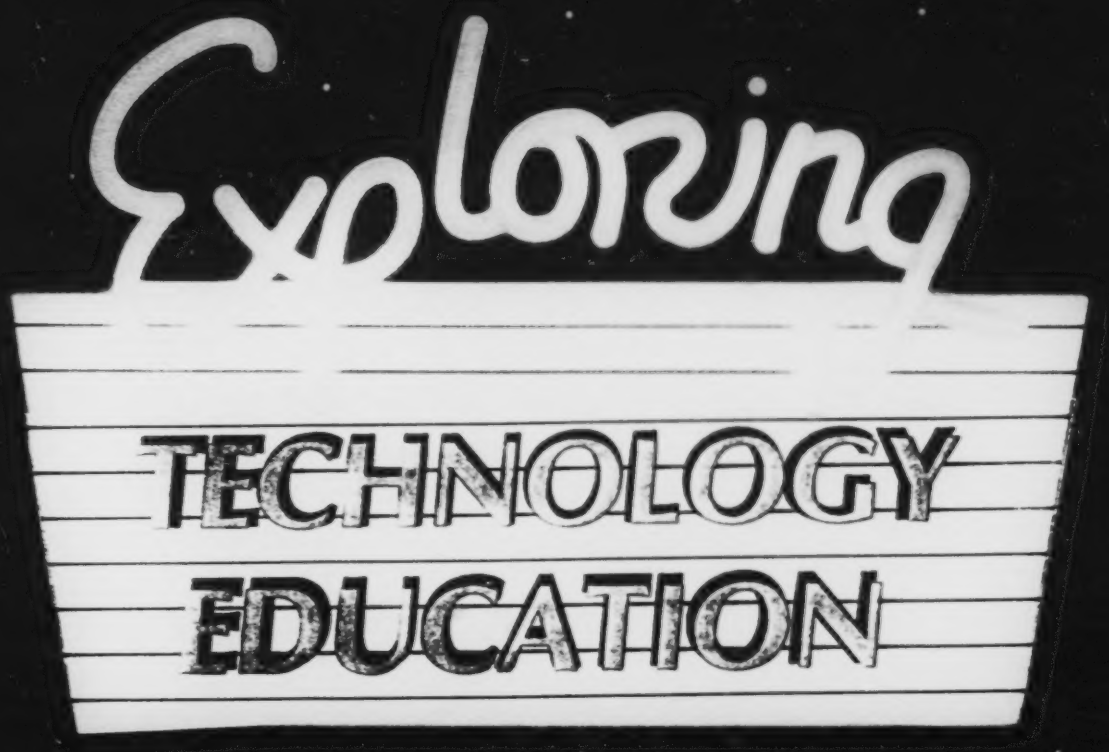
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN OTHER THAN PAPER COPY HAS BEEN GRANTED BY

A Pott

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

BEST COPY AVAILABLE

CE 074576



Exploring Manufacturing Technology

Teacher Edition

MAVCC

BEST COPY AVAILABLE

Exploring Technology Education:

Exploring Manufacturing Technology

Teacher Edition

Written by

John D. Joerschke, Technical Writer

Project coordinated by

Sue Jones, Curriculum Specialist
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

Board of Directors

Jean McEntire, Arkansas, Chair
Sue Ethelbah, Alaska, Vice-Chair
Jim Fliehler, Iowa, Parliamentarian
Mervin Birdwell, Louisiana
Ben Clay, Kansas
Emmett Eary, Texas
Charles Hopkins, Oklahoma
Larry Nelson, South Dakota
Harley Schlichting, Missouri

Clark R. Harris, Executive Director

97-012640

301501

Cover art courtesy of the Agency for Instructional Technology (AIT).

©1997 by the Multistate Academic and Vocational Curriculum Consortium, Inc.

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission from the publisher.

Printed in the United States of America by the
Oklahoma Department of Vocational and Technical Education
Stillwater, OK 74074-4364

Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, OK 74074-4364

The Multistate Academic and Vocational Curriculum Consortium (MAVCC) does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

Exploring Manufacturing Technology

Teacher Edition

Table of Contents

Foreword	v
Acknowledgments	vii
Use of introductory materials	ix
Use of this publication	xi
Competency profile	xv
Instructional/task analysis	xvii
Academic and workplace skill classifications and definitions	xix
Related academic and workplace skills list	xxi

Teacher page

Suggested Activities	1
Learning Activities Sheet	5
Teacher Supplement 1—Using the AIT Media Programs	7
Optional Assignment Sheet 1—AIT Media Questions for Discussion and Review	11
Answers to Assignment Sheets	17
Teacher Supplement 2—Attachment-Point Construction Diagram	21
Optional Lab Activity Sheet 1—Form, Cast, and Condition a Paperweight Casting	23
Written Test	29
Answers to Written Test	33
Unit Evaluation Form	35

Foreword

Exploring Technology Education: Exploring Manufacturing Technology is one of five new publications that have been developed to replace MAVCC's original technology education series. The titles of the five new books in MAVCC's current technology education series are

- *Introduction to Technology Education*
- *Exploring Communication Technology*
- *Exploring Manufacturing Technology*
- *Exploring Construction Technology*
- *Exploring Energy, Power, and Transportation Technology*

The changes in the instructional materials in MAVCC's new technology education series reflect the changes that have occurred in industry as a result of emerging technology and the demand for more highly skilled workers who can read, write, find and interpret information, think creatively to solve problems, and then, effectively communicate their solutions to other people. As a result, the students who will use these instructional materials are asked to learn and use strategies for finding and presenting pertinent information and for thinking and problem-solving to complete the assignment and lab activity sheets that are the core of each unit of instruction in the series.

The success of this publication is due in large part to the capabilities of the personnel who worked with its development. Appreciation is extended to them for their valuable contributions to the publication.

These instructional materials are designed for student use and to assist instructors in organizing and improving instruction. These instructional materials are based on the curriculum-alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching those objectives (information, assignment, and lab activity sheets), and assessing to those same objectives (written test—a criterion-referenced evaluation instrument).

Every effort has been made to make these instructional materials basic, readable, and by all means, usable. However, as with all of MAVCC's instructional materials, instructors must localize and personalize these materials to meet their community, classroom/laboratory, and individual student's situation. Instructors are encouraged to supplement the instructional materials and to develop strategies for motivating their students.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improving the materials, please call or write us.

Jean McEntire, Chair
Board of Directors
Multistate Academic and
Vocational Curriculum Consortium

Clark R. Harris
Executive Director
Multistate Academic and
Vocational Curriculum Consortium

Acknowledgments

Appreciation is extended to those individuals who contributed their time and talent to the development of *Exploring Technology Education: Exploring Manufacturing Technology.*

Thanks are extended to the following technology-education instructors who assisted the MAVCC staff in planning the revisions needed in the original technology-education series.

Steve Adams
Technology Education Instructor
Cleveland High School
Cleveland, Oklahoma

Gail Cobb
Technology Education Instructor
Pawhuska High School
Pawhuska, Oklahoma

Troy Bowers
Technology Education Instructor
Hobart High School
Hobart, Oklahoma

Bobby Welch
Technology Education Instructor
Olustee Jr/Sr High School
Olustee, Oklahoma

Thanks are also extended to the following members of the Technology Education Division of the Oklahoma Department of Vocational and Technical Education for reviewing the rough drafts of the units of instruction as they were developed for this publication.

Lynn Hawkins
State Program Administrator

Donovan Bowers
Program Specialist

Harold Holley
Program Specialist

Thanks are extended, also, to Bob Davis, art department manager; Kim Hale and Suzi Currier, artists; Rose Primeaux, word processing supervisor; Karen Hart, word processing/desktop publishing operator; and the other employees of the Oklahoma Department of Vocational and Technical Education who assisted in the printing of these instructional materials.

Appreciation is also extended to the Agency for Instructional Technology (AIT) for providing the artwork used on the covers of the student and teacher editions of this publication.

Use of Introductory Materials

Introductory materials are included in the teacher edition only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information—such as the table of contents, foreword, and acknowledgments page—information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This profile should become a part of the student's permanent course records.

3. **Instructional/task analysis**—Provides a quick review of the contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Academic and workplace skill classifications and definitions**—Defines the basic-skill classifications used by MAVCC. Skill areas reflected by skill groups, subskills, and descriptions have been identified using *What Work Requires of Schools: A SCANS Report for America 2000 and Workplace Basics: The Skills Employers Want.* These have been adapted by MAVCC.

5. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and lab activity sheets) according to the related academic and workplace skills and competencies being reinforced.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

The instructional unit in the student edition of this publication includes the following components: objective sheet, information sheet, assignment sheets, lab activity sheets, and student supplements.

The teacher edition includes the following components: suggested activities, learning activities sheet, optional assignment sheet, answers to assignment sheets, optional lab activity sheet, teacher supplements, written test, answers to written test, and unit evaluation form.

Units of instruction are designed for use in more than one lesson or class period of instruction, all of the unit components focus on measurable and observable learning outcomes, and careful study of the components in both the student and teacher edition for each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for teacher demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Student-edition components

It is a challenge to keep students motivated. Instructors should supplement the student-edition components by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each of the student components listed below can best be taught, and by allowing students to become involved in preparing and planning their teaching/learning experiences.

Objective sheet. Each unit of instruction is based on performance objectives that state the goals for successful completion of the unit. These performance objectives are presented in two forms on the objective sheet: (1) a unit objective, which states the expected performance of each student after completion of the unit of instruction, and (2) specific objectives, which state what the student must do to reach the unit objective.

The instructor should stress the unit objectives throughout the teaching/learning process. Doing so will help answer student questions concerning performance requirements for each instructional unit. The objectives can also help the instructor determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives to an objective sheet in order to meet the needs of the students and community. When objectives are added, however, the teacher should remember also to add the needed information-sheet, assignment-sheet, lab-activity-sheet, and criterion-referenced written-test items.

Information sheet. The information sheet provides the students with the content essential for meeting the testable cognitive (knowledge) objectives of the unit; this means the cognitive information presented in the information sheet is tested in the criterion-referenced written test that is presented in the teacher edition for each unit of instruction.

Student supplements. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students must be able to apply in order to complete one or more of the assignment sheets or lab activity sheets in a unit of instruction. Students are not directly tested over the cognitive information presented in a supplement; however, their ability to apply this information should be evaluated in scoring the completed assignment sheet/lab activity sheet associated with a supplement.

Assignment sheets. The assignment sheets presented in a unit of instruction provide students with pencil-and-paper activities that give students the opportunity to apply the testable cognitive objectives presented in the information sheet and the nontestable cognitive information presented in student supplements. Criteria are provided on each assignment sheet to assist the instructor in objectively evaluating student performance.

Lab activity sheets. The lab activity sheets presented in a unit of instruction provide students with psychomotor activities that give students the opportunity to apply the testable cognitive objectives presented in the information sheet and the nontestable cognitive information presented in the student supplements.

A worksheet is included in each lab activity sheet. The worksheet provides criteria to allow the instructor to objectively evaluate student performance of the particular psychomotor skills presented in a lab activity sheet and also requires the student to check with the instructor to discuss the methods, equipment, and materials the student is planning to use in completing the psychomotor activity in that lab activity sheet.

Teacher-edition components

Suggested activities. The suggested-activities component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan and a list of suggested resources to be used with each unit of instruction.

The teacher should read the instructional-plan section of the suggested-activities component before presenting the unit to his or her students and decide how each objective can best be presented, how to obtain supplemental materials required for the unit presentation, and which outside resources will be required for the unit presentation.

The teacher should read both subsections of the "suggested resources" section of the suggested activities to obtain ordering information for books and media to supplement the subject area covered in a unit of instruction.

The subsection called "resources used in developing this unit" lists the books and materials that were used by the writer in doing research for a particular unit of instruction. These materials can be used by the teacher to supplement her or his knowledge of the subject area presented in the unit of instruction or to provide background information to students with particular interests or objectives in the subject area covered in the unit of instruction.

The "suggested supplemental resources" subsection provides ordering information for printed material or media presentations that instructors may want to use to supplement the subject area of the objectives presented in the unit of instruction.

Learning activities sheet. The learning activities sheet supplied in each unit is a step-by-step instruction sheet instructors may copy and distribute to students to guide their individual study through the required components in the student edition (objective sheet, information sheet, student supplements, assignment sheets, and lab activity sheets).

Optional assignment sheets and optional lab activity sheets. When these components are provided in the teacher edition for a unit of instruction, they are pencil-and-paper activities and psychomotor activities. These optional activities may be duplicated for student use. They allow the instructor to use his or her discretion in providing students with additional objectives in the same subject area as the required objectives provided in the student edition.

Assignment-sheet answers. Assignment-sheet answers are designed to assist the teacher in evaluating student performances on both the required assignment sheets in the student edition and the optional assignment sheets in the teacher edition.

Written test. This component is a criterion-referenced evaluation of every cognitive objective listed in the information sheet in the student edition. If the instructor has added, deleted, or modified objectives in the student edition, appropriate changes should be made on the written test. The test is included in the teacher edition only, but duplication is permitted for student use.

Written-test answers. This component is designed to assist the teacher in evaluating student performance on the written test.

Teacher supplements. Teacher supplements are optional materials for the teacher to use. They may provide the teacher with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books or with information they may need to help students complete the required assignments/lab activities in the student edition.

Unit evaluation form. This form provides teachers with a record of each student's performance on a unit of instruction. It includes space for assignment-sheet ratings, lab-activity-sheet ratings, written-test scores, and teacher comments. The unit evaluation form is included in the teacher edition only, but duplication is permitted for student use.

Competency Profile

Name: _____

Directions: Evaluate the student using one of the optional rating scales below. Write the appropriate numbers/letters to indicate the degree of competency achieved. The descriptions associated with each of the numbers/letters focus on a level of student performance for each of the tasks listed. The written-test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Optional rating scales

Option A

Rating scale:
- 4 — **Skilled** – Can perform job with no additional training.
- 3 — **Moderately skilled** – Has performed job during training program; limited additional training may be required.
- 2 — **Limited skill** – Has performed job during training program; additional training is required to develop skill.
- 1 — **Unskilled** – Is familiar with process, but is unable to perform job.
- 0 — **No exposure** – No information or practice provided during training program, complete training is required.
- NA — **Non-applicable**.

Option B

Yes — Can perform job with no additional training.
No — Is unable to perform satisfactorily.

Exploring Manufacturing Technology

_____ 1. Research a manufacturing career

_____ 2. Describe the materials and processes used to produce a finished manufactured product

_____ 3. Plan a production process

_____ 4. Perform a production-process evaluation activity

_____ 5. Fabricate and test composite materials

_____ 6. _____

_____Written-test score

Comments: _____

_____

_____

_____

_____

Evaluator: _____ Date: _____

Permission to duplicate this profile is granted.

Instructional/Task Analysis

Exploring Manufacturing Technology

Related Information: What the student should know	Application: What the student should be able to do
1. Definition of the term *system*	11. Research a manufacturing career
2. Definition of the term *manufacturing system*	12. Describe the materials and processes used to produce a finished manufactured product
3. Definition of the term *manufacturing technology*	13. Plan a production process
4. Definitions of the stages in a basic technology systems model	14. Perform a production-process evaluation activity
5. Definitions of the categories of resources essential for a manufacturing system to produce a product	15. Fabricate and test composite materials
6. Types of the basic industrial materials used in a manufacturing system	
7. Definitions of the methods of processing the basic industrial materials used in a manufacturing system	
8. Definitions of the categories of people resources used in a manufacturing system	
9. Descriptions of the types of production processes used in manufacturing systems	
10. Descriptions of the types of automation used in manufacturing systems	

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner.
	Arithmetic/ mathematics	Performing basic computations, applying estimating and reasoning skills, and solving practical problems using a variety of mathematical techniques.
	Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques.
	Listening	Receiving, interpreting, and responding to verbal messages and other cues.
	Speaking	Communicating a thought, idea, or fact verbally in a clear, concise manner.
Thinking skills	Creative thinking	Using imagination to generate new ideas.
	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative.
	Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results.
	Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information.
	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills.
	Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem.
Personal-management skills	Responsibility	Exerting a high level of effort towards goal attainment, working hard to become excellent at doing tasks by setting high standards, paying attention to details, and displaying a high level of concentration.
	Self-esteem	Developing self-confidence and maintaining a positive view of self.
	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress.
	Integrity/honesty	Choosing an ethical course of action when faced with making a decision that may break with personal or societal values and recognizing the impact of violating these beliefs and codes on an organization, self, and others.
	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.

Academic and Workplace Skill Classifications and Definitions

Skill group	Subskill	Definition
Resources	Time	Selecting relevant, goal-related activities; ranking them in order of importance; allocating time; and understanding, preparing, and following schedules.
	Money	Using or preparing budgets, making forecasts, keeping records, and making adjustments to meet objectives.
	Material and facilities	Acquiring, storing, and using materials and space efficiently.
	Human resources	Assessing skills and distributing work accordingly; evaluating performance and providing feedback.
Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal.
	Coaching	Helping others learn new skills.
	Leadership	Communicating ideas to justify position; accepting responsibility for others; and encouraging, persuading, convincing, or otherwise motivating an individual or group.
	Negotiation	Resolving conflict between two or more individuals through discussion and compromise.
	Customer service	Working and communicating with customers to satisfy their expectations.
	Cultural diversity	Working well with men and women with a variety of ethnic, social, or educational backgrounds.
Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy.
	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way.
	Interpretation	Selecting and analyzing information and communicating the results to others.
	Processing	Using computers to acquire, organize, analyze, and communicate information.
Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively.
	Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions.
	Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems.
Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies.
	Application	Demonstrating proper procedures for setting up and operating equipment.
	Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies.

Related Academic and Workplace Skills List

Exploring Manufacturing Technology

Task	Skill group	Subskill	Definition
Research a manufacturing career (A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Knowing how to learn	Using efficient learning techniques to acquire and apply new knowledge and skills
	Personal-management skills	Career awareness, development, and mobility	Assessing self accurately, setting personal goals, establishing and implementing a plan, and monitoring progress
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Interpretation	Selecting and analyzing information and communicating the results to others
Describe the materials and processes used to produce a finished manufactured product (A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Information	Interpretation	Selecting and analyzing information and communicating the results to others
Plan a production process (A.S. 3)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Creative thinking	Using imagination to generate new ideas
		Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
A. S. 3 (cont.)		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively
		Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions
		Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
Perform a production-process evaluation activity (L.A.S. 1)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information
		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Resources	Time	Selecting relevant, goal-related activities; ranking them in order of importance; allocating time; and understanding, preparing, and following schedules
		Material and facilities	Acquiring, storing, and using materials and space efficiently

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
L. A. S. 1 (cont.)	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal
	Information	Acquisition and evaluation	Identifying need for data, obtaining it from existing sources or creating it, and evaluating its relevance and accuracy
		Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way
		Interpretation	Selecting and analyzing information and communicating the results to others
	Systems	Interrelationships	Knowing how social, organizational, and technological systems work and operate effectively
		Monitoring	Distinguishing trends, predicting impact of actions on system operations, diagnosing deviations in systems' performance, and correcting malfunctions
		Modification and design	Making suggestions to modify existing systems to improve products or services, and developing new or alternative systems
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies
Fabricate and test composite materials (L.A.S. 2)	Basic skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task
		Writing	Communicating a thought, idea, or fact in written form in a clear, concise manner
		Arithmetic/ mathematics	Performing basic computations
		Science	Applying knowledge learned through study and practice that is based on scientific principles, methods, and techniques
	Thinking skills	Decision making	Specifying goals and constraints, generating alternatives, considering risks, and evaluating and choosing the best alternative
		Problem solving	Recognizing and defining problems, devising and implementing a plan of action, and tracking and evaluating results
		Seeing things in the mind's eye	Mentally organizing and processing symbols, pictures, graphs, and other information

Related Academic and Workplace Skills List

Task	Skill group	Subskill	Definition
L. A. S. 2 (cont.)		Reasoning	Applying a rule or principle underlying the relationship between two or more objects when solving a problem
	Resources	Material and facilities	Acquiring, storing, and using materials and space efficiently
	Interpersonal skills	Teamwork	Working cooperatively with others to reach a common goal
	Information	Organization and storage	Organizing, processing, and maintaining written or computerized records and other forms of information in a systematic way
		Interpretation	Selecting and analyzing information and communicating the results to others
	Technology	Selection	Choosing procedures, tools, or equipment including computers and related technologies
		Application	Demonstrating proper procedures for setting up and operating equipment
		Maintenance and troubleshooting	Preventing, identifying, or solving problems with equipment, including computers and other technologies

Exploring Manufacturing Technology

Suggested Activities

Instructional plan

Preparation

- Review the student components presented for this unit in the student edition.

  — Objective Sheet
  — Information Sheet
  — Assignment Sheet 1, "Research a Manufacturing Career"
  — Student Supplement 1, "Examples of Some of the Careers in the Manufacturing Area"
  — Assignment Sheet 2, "Describe the Materials and Processes Used to Produce a Finished Manufactured Product"
  — Student Supplement 2, "Elements of the Methods Used to Process the Basic Industrial Materials"
  — Assignment Sheet 3, "Plan a Production Process"
  — Student Supplement 3, "Production-Process Planning"
  — Lab Activity Sheet 1, "Perform a Production-Process Evaluation Activity"
  — Lab Activity Sheet 2, "Fabricate and Test Composite Materials"
  — Student Supplement 4, "Composite Materials Used in Airframe Manufacturing"
  — Student Supplement 5, "Wing-Spar Pattern"

  Review the teacher components presented for this unit in this teacher edition.

  — Learning Activities Sheet
  — Teacher Supplement 1, "Using the AIT Media Programs"
  — Optional Assignment Sheet 1, "AIT Media Questions for Discussion and Review"
  — Answers to Assignment Sheets
  — Teacher Supplement 2, "Attachment-Point Construction Diagram"
  — Optional Lab Activity Sheet 1, "Form, Cast, and Condition a Paperweight Casting"
  — Written Test
  — Answers to Written Test
  — Unit Evaluation Form

  The **Learning Activities Sheet** is a step-by-step instruction sheet you may copy and distribute to your students to guide their individual study through the required components in the student edition (Objective Sheet, Information Sheet, Assignment Sheets, Student Supplements, Lab Activity Sheets).

  Note that Step 3 on this Learning Activities Sheet asks the student to watch unnamed media presentations and complete the questions for discussion and review.

Suggested Activities

You may obtain and show the AIT media presentations designed to go with this unit. **Teacher Supplement 1, "Using the AIT Media Programs,"** summarizes the content of these presentations (see the Suggested Supplemental Materials section below for ordering information).

If you select the AIT media presentations, write the names of those media presentations on the blank line in the Learning Activities Sheet, or if you have selected other media presentations to use with your class, write in the title of those presentations.

If you use the AIT media presentations, you may use **Optional Assignment Sheet 1** in Step 3, which asks students to complete questions for discussion and review. If you use other media presentations, you should prepare your own questionnaire to be used with Step 3 on the Learning Activities Sheet and title it "Questions for Discussion and Review."

Teacher Supplement 2, "Attachment-Point Construction Diagram," is a diagram of the attachment point students will use in strength-to-weight testing of the wing spars they will construct in Lab Activity Sheet 2 in the student edition. The instructor will need to construct one or more of these attachment points before the students can complete the activity as outlined in the student edition.

Optional Lab Activity Sheet 1, "Form, Cast, and Condition a Paperweight Casting," is an optional lab activity sheet that you may want to use with your students to further illustrate the methods used to process industrial materials.

- Modify the Learning Activities Sheet as needed to reflect your instructional plan. Copy and prepare the Learning Activities Sheet for distribution to your students.
- Copy and prepare the teacher components you select to distribute to your students (Written Test, Unit Evaluation Form).
- Prepare the classroom by putting up posters and charts and displaying articles and other references related to the objectives of this unit.

Delivery and application

Have students complete the steps in the Learning Activities Sheet, "Exploring Manufacturing Technology."

Evaluation

- Evaluate the assignment sheets. See the evaluation criteria listed at the top of each assignment sheet as well as the teacher page **Answers to Assignment Sheets**.
- Evaluate the lab activity sheets. See the evaluation criteria listed on the worksheet that accompanies each lab activity sheet.
- Give the written test. See the teacher page **Written Test**.
- Evaluate the written test. See the teacher page **Answers to Written Test**.

Suggested Activities

- Compile written-test, assignment-sheet, and lab-activity-sheet scores. See the teacher page **Unit Evaluation Form**.
- Reteach and retest as required.

Suggested resources

Resources used in developing this unit

Print media

- Buck, Sue, Kevin Allen, and Eric Davis. *Exploring Aeronautics and Space Technology.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1991.
- Murray, Steve. *Exploring Technology Education,* 2nd ed. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1991.

Suggested supplemental resources

- AIT media programs, copyright 1990:

  Introduction to Manufacturing

  Manufacturing Systems

  Manufacturing Materials

  Manufacturing Processes

  Manufacturing Planning and Production

  Available from:

  Agency for Instructional Technology (AIT)
  Box A
  Bloomington, Indiana 47402

  Phone: (800) 457-4509 or (812) 339-2203

Exploring Manufacturing Technology

Learning Activities Sheet

Put a checkmark in each blank as you complete each of the steps below.

_____	1.	**Read**	Objective Sheet.
_____	2.	**Study**	Information Sheet.
_____	3.	**Watch**	Media presentations _____
			_____
		and	
		Complete	"Questions for Discussion and Review."
_____	4.	**Read**	Student Supplement 1, "Examples of Some of the Careers in the Manufacturing Area."
_____	5.	**Do**	Assignment Sheet 1, "Research a Manufacturing Career."
_____	6.	**Stop**	Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 7. If the evaluation is not satisfactory, repeat Steps 4 and 5.
_____	7.	**Read**	Student Supplement 2, "Elements of the Methods Used to Process the Basic Industrial Materials."
_____	8.	**Do**	Assignment Sheet 2, "Describe the Materials and Processes Used to Produce a Finished Manufactured Product."
_____	9.	**Stop**	Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 10. If the evaluation is not satisfactory, repeat Steps 7 and 8.
_____	10.	**Read**	Student Supplement 3, "Production-Process Planning."
_____	11.	**Do**	Assignment Sheet 3, "Plan a Production Process."
_____	12.	**Stop**	Have your instructor evaluate the completed assignment sheet. If the evaluation is satisfactory, continue to Step 13. If the evaluation is not satisfactory, repeat Steps 10 and 11.
_____	13.	**Do**	Lab Activity Sheet 1, "Perform a Production-Process Evaluation Activity."
_____	14.	**Stop**	Have your instructor evaluate the completed lab activity. If the evaluation is satisfactory, continue to Step 15. If the evaluation is not satisfactory, repeat Step 13.

Continue to next page.

_____ 15.	**Read**	Student Supplement 4, "Composite Materials Used in Airframe Manufacturing," and Student Supplement 5, "Wing-Spar Pattern."
_____ 16.	**Do**	Lab Activity Sheet 2, "Fabricate and Test Composite Materials."
_____ 17.	**Stop**	Have your instructor evaluate the completed lab activity. If the evaluation is satisfactory, continue to Step 18. If the evaluation is not satisfactory, repeat Steps 15 and 16.
_____ 18.	**Stop**	Check with your instructor for any optional activities he or she may choose to assign.
_____ 19.	**Do**	Optional activities listed below.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ 20.	**Stop**	Have your instructor evaluate the optional activities. If the evaluation is satisfactory, continue to Step 21. If the evaluation is not satisfactory, repeat Step 19 as your instructor directs.
_____ 21.	**Take**	Written Test.
_____ 22.	**Stop**	Have your instructor evaluate the completed written test. If the evaluation is satisfactory, proceed to the next learning activities sheet. If your evaluation is not satisfactory, ask your instructor for directions for reviewing the information in this unit.

Permission to duplicate this form is granted.

Teacher Supplement 1—Using the AIT Media Programs

Note

A series of five AIT media programs were designed to supplement this unit, "Exploring Manufacturing Technology": (1) "Introduction to Manufacturing," (2) "Manufacturing Systems," (3) "Manufacturing Materials," (4) "Manufacturing Processes," and (5) "Manufacturing Planning and Production." Summaries and objectives for each of these five programs are given below.

Program name

AIT media "Introduction to Manufacturing"

Program summary

This program introduces manufacturing technology—its system components, devices, technological advances, and relationship to other technology systems. It focuses on the impact manufacturing technology has made on people as manufacturing produces goods that meet people's needs and wants.

Defining *manufacturing* as "changing materials into usable products in a workshop or factory," the program opens with a survey of manufacturing in the past. Dramatic re-creations and archival footage show the primitive creation of flint tools, weaving for domestic use and occasional barter, making shoes in a mercantile society, then Henry Ford and the development of the assembly line and the use of standardized parts. The program analyzes the manufacture of Model T Fords in terms of the universal systems model, and describes how the development of assembly-line manufacturing brought about massive urban migration and the growth of cities.

The second revolution in manufacturing came with the introduction of robotics, resulting in less boring and dangerous work for people, but also in fewer unskilled jobs. Manufacturing has created many other jobs, however, including those in advertising, shipping, sales, and construction. It has also brought about environmental problems such as air pollution, toxic chemical waste, and chlorofluorocarbons. Viewers see the Distronics plant in Huntsville, Alabama, where compact discs are made under tight conditions of purity and quality control. The worker responsible for checking the quality of the master tapes is profiled, and compact-disc manufacturing is also analyzed in terms of the systems model. In the future, manufacturing may occur in space, which is a pure and gravity-free environment.

Program objectives

The media program is designed to illustrate

- the historical development, current status, and future possibilities of manufacturing technology.
- the impact of manufacturing technology on society and the environment.
- how the systems model applies to manufacturing (input, process, and output, with a feedback loop).

Teacher Supplement 1

Program name

AIT media "Manufacturing Systems"

Program summary

This program introduces the three major types of manufacturing systems and the four essential resources necessary for a manufacturing system to succeed.

The program opens by introducing the three manufacturing systems: (1) custom, (2) intermittent, and (3) continuous. A colonial craftsperson making shoes and a modern violin-maker, who is profiled, are examples of **custom** manufacturing producing handmade products, one at a time. A modern printing plant printing jobs to fill customer orders is an example of **intermittent** manufacturing in a job shop. The program then visits Intergraph Computers, a large plant where highly automated, assembly-line production is used in a **continuous** manufacturing system to make CAD-CAM computer systems. Viewers see how all components—chips, memory boards, switches, wires, and monitors—are tested separately and then assembled and retested. Leroy Cole, director of manufacturing engineering, is profiled as he explains the exhaustive quality-testing process.

The second part of the program introduces the four essential resources for manufacturing—**finance**, **materials**, **people**, and **facilities**—and tells the story of Steven Wozniak and Steven Jobs, founders of Apple Computer Company. They started with an idea and expertise and then acquired materials, financing, and finally, a large, modern facility. The story is analyzed in terms of the systems model, in which the four resources provide the input, the manufacture of computers is the process, the finished computers are the output, and their success and sales constitute the feedback. In the future, talking computers may be common. Students are asked, "How will computers change manufacturing?"

Program objectives

The media program is designed to illustrate

- different types of manufacturing systems.
- essential elements involved in a manufacturing enterprise.

Program name

AIT media "Manufacturing Materials"

Program summary

This program presents the use, testing, and improvement of materials used in manufacturing. It discusses the origins, properties, and uses of five categories of materials, their usefulness for different products, and the importance to industry of testing the properties of each of these materials.

The program opens with images showing a human-powered aircraft, a bullet-proof vest, and students making various objects in a technology education class. The choice of the right materials has been of primary importance for each case. **Wood**, from trees, is readily available, renewable, and strong. It is useful for many kinds of construction. **Metals**, from mines, must be processed to be used, but they can be recycled. Their strength makes them suitable for many kinds of heavy construction. **Earth**

materials include brick, ceramic tiles, limestone, and glass. These are hard and durable materials and do not conduct heat, making them suitable for insulation. **Plastics** are derived from oil. They are light, flexible, and can be either soft or hard; they do not conduct electricity, making them especially useful in electronics. **Composites** consist of two or more materials bonded together, such as concrete or fiberglass. Kevlar, a new composite, is light, strong, and supple; it makes an excellent bullet-proof vest.

The program leads viewers to Battelle Laboratories, where industries send their products for testing. Credit cards are tested for strength, flexibility, and ability to withstand forgery. Running shoes are battered to test their strength and durability. In the Louisville Slugger factory and at a softball diamond, viewers are asked to compare the properties of wooden and aluminum bats. Which bat is better? In the future, cryogenics may become increasingly important in treating materials; subjecting industrial materials to extremely cold temperatures and then reheating them slowly makes them stronger and longer-lasting.

Program objectives

The media program is designed to illustrate

- the origins and uses of five common manufacturing materials.
- the properties of manufacturing materials.
- how some properties of materials are tested in industry.
- how the properties of materials affect their use in making manufactured products.

Program name

AIT media "Manufacturing Processes"

Program summary

This program shows how technology processes raw materials into useful products. Often the same material can be used for very different products, depending on the way it is processed. Wood can be furniture or a violin; iron may be part of a jet fighter or the engine block of a car; salt from a salt mine may end up on the dinner table or on icy sidewalks.

The program introduces six manufacturing processes.

1. **Separating** involves removing one thing from another, as when meat is cut. Cutting can be done with water jets or computer-driven lasers.
2. **Forming** changes the size or shape of something.
3. In **casting** or **molding**, a material in liquid form is poured into a form; as the material hardens, it takes the shape of that form, as, for example, melted chocolate is formed into bars and candies.
4. **Conditioning** involves treating a material with heat, cold, or chemicals to strengthen the material's properties.
5. **Assembling** brings parts together, as, for example, the spokes, rim, and hub are joined to form a bicycle wheel.

6. **Finishing** gives protection or decoration to a product.

A visit to a Chrysler Corporation foundry demonstrates some of these processes and shows how new technology has saved a company and made work there safer and physically easier. Henry Crews, an industrial engineer, shows how engine blocks are made, starting from scrap metal (melted at 3000 degrees Fahrenheit in a cupola) and sand (used in the molds). The process uses the new technology of the "impact mold line." In the future, a StereoLithography may be used to create three-dimensional models. In this process, a designer uses the CAD system to design a new product. Then, a computer directs a laser that can sculpt plastic in intricate detail and according to the designer's plans.

Program objectives

The media program is designed to illustrate

- the six manufacturing processes.
- examples of new trends in manufacturing technology.

Program name

AIT media "Manufacturing Planning and Production"

Program summary

This program is about planning in manufacturing—planning for quality control, planning for productivity, and planning for new products.

The program opens with a humorous scene from a business office with the soundtrack running double time to emphasize that planning for speed and efficiency is necessary to stay ahead of the competition. A visit to a B.F. Goodrich plant that makes braking systems demonstrates the role of **planning for quality control**. Travis Deal, senior quality inspector, describes the statistical process control (SPC) system and how it works to ensure the quality of the product. At Melroe Manufacturing, makers of Bobcat vehicles, **planning for productivity** has enabled the company to produce more vehicles, more cheaply, in less time. The plant has found it more efficient to buy cheaper, unoiled steel, and then treat it themselves; to use high-technology automatic-guided vehicles (AGVs) to carry chassis around; to take advantage of CAD-CAM design processes; and to institute just-in-time manufacturing to avoid warehousing and inventory costs.

At the headquarters of Sunrise Publications, viewers witness a committee deciding new card lines and designs, and visit briefly with an artist. Product manager Kim Turner describes the planning process, which includes market research and sales reports. A visit to the print shop in August shows Christmas cards coming off the press; planning must be done months in advance. Other committees must plan for inventory, sales, and facilities. The program concludes by reviewing several technologies of the future and asking students, "What changes would you like to plan?"

Program objectives

The media program is designed to illustrate

- the importance of planning in the manufacture of a product.

Optional Assignment Sheet 1—AIT Media Questions for Discussion and Review

Name _____ Date _____

Evaluation criteria	Rating
Directions have been followed.	_____
Student responses are relevant and well thought out.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Directions As you watch the following AIT media presentations, answer the following questions in the space provided below each question.

Part A **AIT media, "Introduction to Manufacturing"**

Discussion/ review questions

1. What is *manufacturing*?

2. What is one of the earliest examples of manufacturing discussed in the media program?

3. Describe some of the major developments that have occurred in manufacturing technology.

4. In general, how has manufacturing changed?

5. What products were discussed as examples of "manufactured" products in the media program?

6. Use the terms of the universal systems model—input, process, output, and feedback—to describe the manufacture of a car.

7. What will manufacturing technology be like in the future and how will it affect us?

Part B AIT media, "Manufacturing Systems"

1. What is a *system*?

2. What are the three types of manufacturing systems? Give an example of each type from the media program.

3. What are the essential elements necessary for manufacturing? Give an example of each type.

4. Describe the manufacturing system in terms of the systems model.

5. Describe Apple computer in terms of changes in their manufacturing system and the essential elements in manufacturing, from the building of their initial computer to present-day operations.

Part C AIT media, "Manufacturing Materials"

1. What are the five major types of manufacturing materials discussed in the media program and what is the origin of each type?

2. Why are different materials used in different applications?

3. What are some applications of materials illustrated in the media program?

4. What properties would a material need to possess to be used for a football helmet? a cooking pot or container? a pillow? a ladder for working near electrical lines? water skis? handles on a cooking pan?

5. What are examples of composites? What are examples of earth materials?

6. What are two reasons for using aluminum instead of steel for manufacturing soft-drink cans?

7. What example is given in the media program of a material used on a limited basis because of environmental hazards?

8. Could a human-powered plane have crossed the English Channel 30 years ago?

Part D AIT media, "Manufacturing Processes"

1. What is *processing* and why is it important?

2. What are the six types of manufacturing processes? Define and give an example of each type.

3. How did changes in the way Chrysler processes materials affect the company?

4. What new ways of processing materials are illustrated in the media program?

Part E AIT media, "Manufacturing Planning and Production"

1. What are the three types of planning a company must do?

2. What is SPC and how does it work?

Optional Assignment Sheet 1

3. How has technology changed the way employers work with their machines?

4. Describe the ways computers were used for planning and production in manufacturing in the examples shown in the media program.

5. What is *just-in-time manufacturing*?

6. Describe some of the planning procedures done at B.F. Goodrich, Melroe, and Sunrise.

7. As manufacturing becomes more complex in the future and new technology brings about new materials, processes, and products, what changes would you like to plan?

Answers to Assignment Sheets

Answers to assignment sheets in student edition

Assignment Sheet 1—Answers will vary. Student performance should be evaluated according to the criteria listed on the assignment sheet.

Assignment Sheet 2—Answers will vary. Student performance should be evaluated according to the criteria listed on the assignment sheet.

Assignment Sheet 3—Answers will vary. Student performance should be evaluated according to the criteria listed on the assignment sheet.

Answers to optional assignment sheet in student edition

Assignment Sheet 1

Part A—AIT media, "Introduction to Manufacturing"

1. *Manufacturing* is changing materials into usable products in a workshop or factory.

2. Handmade weapons for protection and for hunting

3. First, people began manufacturing products for their own use. Then, some people exchanged goods or services with others through the barter system. Next, people began to specialize in their crafts and make enough goods to sell for a profit; the mercantile system began when merchants bought from the craftspeople and sold to others. The Industrial Revolution led to factories, the assembly line, interchangeability of parts, and the mass production of products. These developments led to the concentration of people in cities. Recent developments include robotics and the possibility of manufacturing in orbiting space factories.

4. Work is cleaner and involves less physical labor and drudgery. More unskilled work is being done by robots, so fewer jobs are available for unskilled workers. Machines today are more capable of higher productivity and quality.

5. CO_2 cars, automobiles, compact discs, chocolate bars, pinball machines, tennis shoes

6. **Input**—people, money, energy, materials

   Process—assembly-line manufacturing process

   Output—finished car

   Feedback—popularity, many sales

7. Manufacturing processes in the future will include more restrictions for environmental reasons, fewer low-skilled jobs, and intelligent androids. These are the answers students should mention, but other answers are also acceptable.

Answers to Assignment Sheets

Part B—AIT media, "Manufacturing Systems"

1. A *system* is a collection of several parts that work together for one purpose.

2. **Custom manufacturing**—Producing items one at a time; example, violins

   Intermittent manufacturing—Producing products in limited production runs to fill customer orders; example, greeting cards

   Continuous manufacturing—Mass-producing great numbers of a product in a continuous run; example, computers

3. **Finance**—examples, money from investors, banks, and stock sales

   Materials—examples, paper and ink for greeting cards; wood and varnish for violins; and chips, wires, and switches for computers

   People—examples, people who design, manage, organize, and work in manufacturing

   Facilities—examples, workshops and factories where products are produced

4. **Inputs**—finance, materials, people, and facilities

   Processes—the various manufacturing processes: casting and molding, assembling, etc.

   Outputs—manufactured products (computers, jeans, candy bars, etc.)

   Feedback—the response of the public to the products and the product quality—sales

5. Originally, the computers were hand-assembled, one at a time—the custom system. The company progressed until it was able to manufacture computers continuously. Financing of the operation began with personal investing, then bank loans, then stock sales. Originally, "facilities" consisted of a garage workshop, but the company now has highly automated factories.

Part C—AIT media, "Manufacturing Materials"

1. **Wood**—comes from trees

   Metals—come from ores in the ground and in the sea

   Plastics—made from oil products

   Earth materials—come from the earth's crust

   Composites—man-made materials that are made from combinations of some of the other types of materials

2. Properties of materials lend themselves to specific applications; for example, plastics are used to enclose electronic equipment because plastics do not conduct electricity and, therefore, protect users from shock.

3. Wood for framing houses; ceramic tiles for a space shuttle; Kevlar for bullet-proof vests, etc.

4. **Football helmet**—Strength to withstand an impact

   Cooking pot—Ability to conduct heat

   Pillow—Soft, cushiony, resilient

   Ladder—Strong enough to support weight, an insulator

   Water skis—Ability to float in water; strong enough to withstand the shock of hitting the water

   Handles on a cooking pan—Should not conduct heat (an insulator)

5. **Composites**—Concrete, fiberglass, Kevlar, plywood, particleboard, carbide tools, graphite composites, etc.

   Earth materials—Ceramic tile, glass, asbestos, diamonds, rock, plaster, clay, etc.

6. Lighter in weight for shipping; readily recyclable

7. Asbestos, a cancer-causing agent

8. No. The light and yet strong materials that are required to manufacture such a plane were not available 30 years ago.

Part D—AIT media, "Manufacturing Processes"

1. *Processing* is the changing of one thing into something else or into a different form or condition. It is important because unprocessed materials do not exist in a state ready for use in manufacturing nor do they exist in a finished-product state.

2. **Separating**—Removing excess material; examples, high-pressure water-jet machining, laser cutting

   Forming—Changing the shape and size of materials without changing their volume; example, bending a glass tube

   Casting—Pouring liquid material into a mold and allowing the material to harden; example, making chocolate candy bars

   Conditioning—Changing the internal structure of a material; example, tempering metal to make it tougher

   Assembling—Bringing parts or materials together and combining them; examples, putting a bicycle together with nuts and bolts, welding etc.

   Finishing—Applying a material to protect and/or improve the appearance of a final product; example, applying a finish to a baseball bat.

3. Changes in the way Chrysler processed materials saved the company by making it more productive and competitive.

4. Robotics, high-pressure water-jet machining, laser machining, StereoLithography, impact-mold production line

Part E—AIT media, "Manufacturing Planning and Production"

1. Planning new products, planning for productivity, and planning for quality control

2. SPC is a system used to understand and predict the quality level and improve the productivity in a manufacturing system. Each machine operator collects data from his or her machine and records it on a chart; a computer translates the chart data into a graphic; if the information indicates a problem, workers form a group to plan solutions.

3. Formerly, people in the trade ran machines more as an art, sometimes by the "seat of their pants." Now, people in the trade treat running their machines more scientifically.

4. CAD-CAM, SPC, figuring how many parts can be cut from any piece of steel

5. In just-in-time manufacturing the raw materials needed in the manufacturing system arrive just in time to be used on the production line. Large warehouses for storing large inventories of raw materials become unnecessary.

6. **B.F. Goodrich** used SPC for quality control.

   Melroe planned for increased productivity by the use of cheaper, untreated steel; the use of automated materials handling; the use of CAD-CAM; and the use of just-in-time manufacturing.

   Sunrise planned for new products (new card lines); planned production schedules so cards could be produced and shipped to the marketplace in time for holiday seasons; and planned inventory, sales, and facilities.

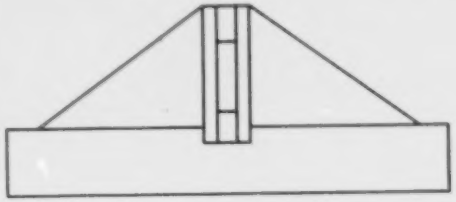
7. Answers will vary.

Teacher Supplement 2—Attachment-Point Construction Diagram

Introduction

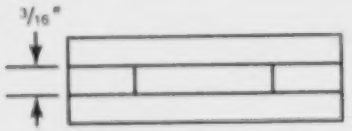
The construction diagram on the following page is of the attachment point students will use in strength-to-weight testing of the wing spars they will construct in Lab Activity Sheet 2 in the student edition. The critical component of this attachment point is the 1-inch-high, ⅜-inch-wide, and 2-inch-deep slot where the spars will be inserted during the testing process. For the tests to be run successfully, the dimensions of this slot must be exact.

The base of the attachment point will be used as a surface for clamping the device to a table or workbench. The size of the base itself is not important as long as the dado groove to be cut in the base is within specified dimensions so that the slot fits snugly into the groove during the testing procedure.

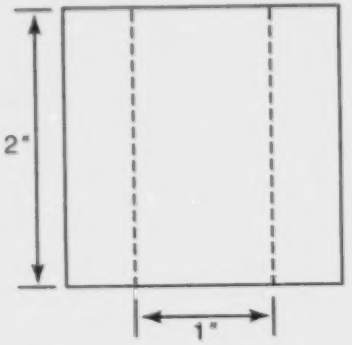


Attachment point should fit very snugly in the dado groove.

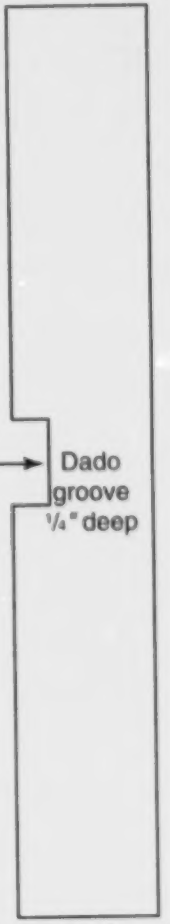
As long as these measurements are correct, the other parts can be any size.



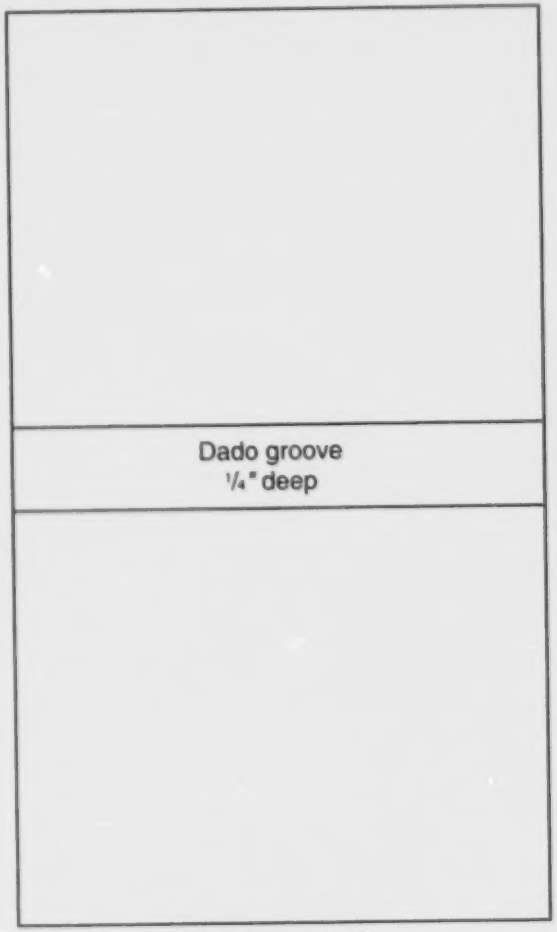
ATTACHMENT POINT (Side view)



ATTACHMENT POINT (End view)



BASE (Side view)



BASE (Top view)

Optional Lab Activity Sheet 1—Form, Cast, and Condition a Paperweight Casting

Introduction

Forming and casting are widely used in manufacturing. Without these two processes, mass production of many common products would be impossible. In this lab activity, you will manufacture a paperweight from clay and use forming and casting in a simple manufacturing process. Besides learning about the processes of forming and casting, you will also learn about the process of conditioning an earth material—clay.

Equipment and materials

- Plaster of paris and manufacturer's instructions
- Model form (see specifications in Step 4 below)
- Container (see specifications in Step 4 below)
- Clay "slip"—Clay mixed with enough water so that the resulting liquid mixture is about the consistency of enamel paint
- Knife or spatula
- Modeling tools
- Paint or sealer

Procedure

Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Review the following worksheet associated with this lab activity.

_____ 2. Complete the pre-performance check (Part A) on the worksheet and receive your instructor's signed approval for the information you have listed for performing the production process.

_____ 3. Review the evaluation criteria listed in the performance evaluation (Part B) on the worksheet.

_____ 4. **Create a mold**:

- Your instructor will provide you with a paperweight mold form from which you will make a plaster-of-paris mold. The paperweight mold form will meet the following specifications:
  - — The form will have a flat base.
  - — The form will be 4 inches wide, 4 inches long, and 4 inches deep.

- Locate a container that meets the following specifications:

  — The container should be about 1 inch wider, 1 inch longer, and 1 inch deeper than the mold form.

- Place the base of the mold form in the bottom of the container.

- Mix the plaster of paris according to the manufacturer's instructions.

- Slowly pour the plaster of paris around and over the mold form until the container is full; lightly tap the container on all sides to release air bubbles from the plaster of paris.

- Allow the plaster of paris to dry according to the manufacturer's instructions.

- Remove the plaster of paris and the mold form from the container.

- Remove the mold form from the plaster of paris by gently tapping on the plaster of paris.

  Note: Be careful not to let the mold form fall or to crack the plaster-of-paris mold.

- Have your instructor evaluate your mold. Make improvements to the mold process as necessary.

_____ 5. **Make a casting**:

- Prepare the clay-slip material to be used in the casting.

- Pour the clay-slip material into the plaster-of-paris mold. Completely fill the mold and allow the slip material to build up slightly above the top of the mold. Level off the slip material with a knife or spatula.

- Allow the slip material to dry in the plaster-of-paris mold.

- Remove the casting from the plaster-of-paris mold by gently tapping the mold to loosen the casting from the mold.

- Clean the mold to prepare it for future castings.

- Have your instructor evaluate your casting. Make improvements to the casting process as necessary.

_____ 6. **Condition the casting**:

- Use modeling tools and additional clay slip to remove any imperfections from the casting.
- Following the paperweight design you created in Part A of the worksheet, use modeling tools to add the desired decorative details to the surface of the paperweight casting. Allow the casting to dry.
- Paint and/or seal the casting. Allow to dry.

_____ 7. Turn in your finished paperweight to your instructor for evaluation.

_____ 8. Return equipment and materials to proper storage.

_____ 9. Your instructor will rate your performance using the evaluation criteria listed in Part B on the worksheet.

Optional Lab Activity Sheet 1

Worksheet—Form, Cast, and Condition a Paperweight Casting

Name _____ Date _____

Part A: Pre-performance check

Complete the following information concerning the paperweight you will design, form, cast, and condition, and then, have your instructor sign on the blank line at the bottom of this page.

- In the space below, or on a separate piece(s) of paper, make sketches to show your design for the paperweight you will be forming, casting, and conditioning in this lab activity. Your sketches must follow the specifications outlined below and should show all the sides of the paperweight.
  - — The finished paperweight will have a flat base.
  - — The finished paperweight must conform to the dimensions of the mold form: 4 inches wide, 4 inches long, and 4 inches deep.
- Describe any special equipment that you will need to use to produce your paperweight design.

Instructor's signature _____

Worksheet—Form, Cast, and Condition a Paperweight Casting

Part B: Performance evaluation

Evaluation criteria	**Rating**
Paperweight design meets the specifications for the paperweight that are listed in Part A.	_____
Paperweight design sketches are clear and accurate.	_____
Finished paperweight is neatly conditioned and meets the specifications for the paperweight that are listed in Part A.	_____
Clean-up and follow-up actions were adequate.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Exploring Manufacturing Technology

Written Test

Name _____ Score _____

1. Define the term *system*. Write your answer on the blank lines provided beside the term below.

   System _____

   _____

2. Define the term *manufacturing system*. Write your answer on the blank lines provided beside the term below.

   Manufacturing system _____

   _____

3. Define the term *manufacturing technology*. Write your answer on the blank lines provided beside the term below.

   Manufacturing technology _____

   _____

4. Define the stages in a basic technology systems model. Write your answers on the blank lines provided beside each of the stages listed below.

   a. **Stage 1: Input** _____

   _____

   b. **Stage 2: Process** _____

   _____

   c. **Stage 3: Output** _____

   _____

   d. **Stage 4: Feedback** _____

   _____

5. Define the categories of resources essential for a manufacturing system to produce a product. Write your answers on the blank lines provided beside each of the terms below and on the next page.

   a. **Financial resources** _____

   _____

b. **Materials resources** _____

_____

c. **People resources** _____

_____

d. **Facilities** _____

_____

6. List the types of basic industrial materials used in a manufacturing system. Write your answers on the blank lines provided below.

a. _____

b. _____

c. _____

d. _____

e. _____

7. Match the methods of processing the basic industrial materials used in a manufacturing system to their correct definitions. Write the correct numbers on the blanks.

_____ a. Treating a material with heat, cold, or chemicals to impart the material with certain desirable properties

_____ b. Applying a protective or decorative finish to the surface of a base material

_____ c. Removing the excess from—changing the volume of—a material to produce a material of a desired size, shape, or finish

_____ d. Combining two or more materials so that they stay together for a definite period of time

_____ e. Changing the size and shape—but not the volume—of a material in its plastic state

_____ f. Pouring or forcing a material in its liquid or semiliquid state into a mold and allowing the material to solidify before removal

1. Separating
2. Forming
3. Casting or molding
4. Conditioning
5. Assembling
6. Finishing

8. Match the categories of people resources used in a manufacturing system to their correct definitions. Write the correct numbers on the blanks.

_____ a. People who conduct tests and inspections to ensure that the product being produced meets certain production standards

_____ b. People who plan the production process, facilities, materials, and production personnel that will be required to produce a particular product, and who conduct time and method studies to constantly improve the production process

_____ c. People who ensure positive relationships between company management, employees, and the consumers in the general public

_____ d. People who work in any of the stages of the production process

_____ e. People who look at the existing product and design new ways to improve that product, or who design new products that they believe consumers will want to buy

_____ f. People who purchase the materials and equipment needed in the production process, and who create schedules for the production personnel needed in the production process

1. Industrial engineers
2. Production-control personnel
3. Quality-control personnel
4. Production personnel
5. Research and development personnel
6. Industrial-relations personnel

9. Describe the types of production processes used in manufacturing systems. Write your answers on the blanks provided beside each of the terms below.

a. **Custom production** _____

_____

_____

b. **Mass production** _____

_____

_____

c. **Intermittent production** _____

_____

_____

10. Match the types of automation used in manufacturing systems to their correct descriptions. Write the correct numbers on the blanks.

_____ a. Computers and computer-controlled machines are used in every stage in the manufacturing system

_____ b. Robots are used in the production process of the manufacturing system

_____ c. Computers are used by engineers and drafters to produce and store the drawings they create in the design stage of the manufacturing system

_____ d. Computer-monitored manufacturing system in which the raw materials necessary to maintain the production process are scheduled to arrive at the factory only as they are needed in the production process

_____ e. Computer-controlled machines are used by the production personnel in the production process of the manufacturing system

_____ f. Computer-controlled machines are used to make different versions of the same product on the same production line in the production process of the manufacturing system

_____ g. Computers are used by engineers and drafters to produce and store the drawings they create in the design stage of the manufacturing system; the computer then translates the stored design into numerical data that is sent directly to computer-controlled machines used in the production process of the manufacturing system

1. Robotics
2. Computer-aided design
3. Computer-aided manufacturing
4. Computer-aided design/computer-aided manufacturing
5. Computer-integrated manufacturing
6. Flexible manufacturing system
7. Just-in-time manufacturing

Permission to duplicate this test is granted.

Exploring Manufacturing Technology

Answers to Written Test

1. Group of people, procedures, equipment, and resources that function together to produce desired results

2. System in which materials and processes are used to produce a product that will be used elsewhere

3. Development of more efficient processes and materials to produce better manufactured products

4. a. The means by which or the point at which something is put into a system

   b. A series of actions or operations occurring in a system

   c. Something produced by a system

   d. The return to the input stage with evaluative or corrective information about the system processes and output

5. a. The money needed to start and maintain the manufacturing system

   b. The physical substances of which the product in the manufacturing system is made

   c. The individuals who design, create, and control the process in the manufacturing system

   d. All the buildings, tools and machines, utilities, and energy resources used in the process in a manufacturing system

6. Answers may appear in any order.

   - Woods
   - Metals
   - Earth materials
   - Plastics
   - Composites

7. a. 4 d. 5
   b. 6 e. 2
   c. 1 f. 3

8. a. 3 d. 4
   b. 1 e. 5
   c. 6 f. 2

Answers to Written Test

9. a. Craftsperson works alone and produces one product at a time

   b. Groups of workers work in a production process divided into steps and using standardized parts and components and automation to produce large quantities of goods

   c. Groups of workers work in a production process using automation to produce products in groups, lots, or batches

10.

a.	5	e.	3
b.	1	f.	6
c.	2	g.	4
d.	7		

Exploring Manufacturing Technology

Unit Evaluation Form

Student name _____ Unit rating _____

Assignment-sheet ratings

Assignment Sheet 1—Research a Manufacturing Career Rating _____

Comments: _____

_____

Assignment Sheet 2—Describe the Materials and Processes Used to Produce a Finished Manufactured Product Rating _____

Comments: _____

_____

Assignment Sheet 3—Plan a Production Process Rating _____

Comments: _____

_____

Lab-activity-sheet ratings

Lab Activity Sheet 1—Perform a Production-Process Evaluation Activity Rating _____

Comments: _____

_____

Lab Activity Sheet 2—Fabricate and Test Composite Materials Rating _____

Comments: _____

_____

Continue to back of this page.

Unit Evaluation Form

List optional assignments and ratings.

Written-test scores

Pretest _____ Posttest _____ Other _____

Comments: _____

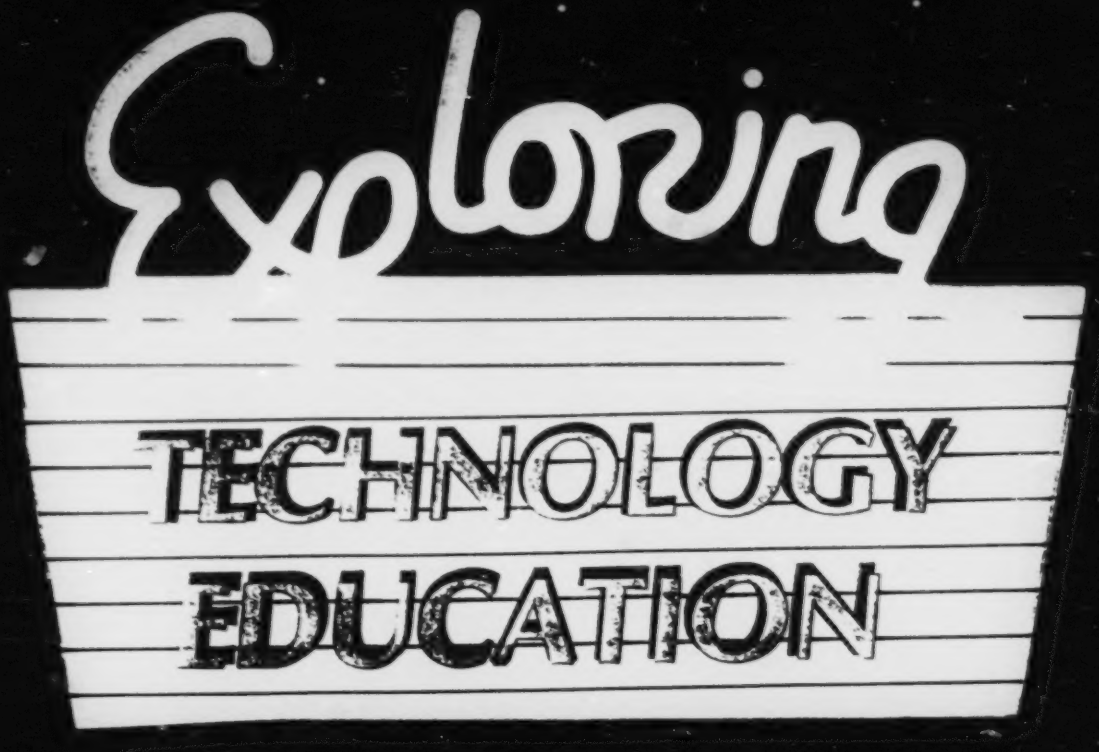
_____

_____

Teacher signature _____ Date _____

Student signature _____ Date _____

Permission to duplicate this form is granted.



Exploring Manufacturing Technology

Student Edition

MAVCC

BEST COPY AVAILABLE

Exploring Technology Education:

Exploring Manufacturing Technology

Student Edition

Written by

John D. Joerschke, Technical Writer

Project coordinated by

Sue Jones, Curriculum Specialist
Multistate Academic and Vocational Curriculum Consortium, Inc.

Project developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

©1997

The Multistate Academic and Vocational Curriculum Consortium (MAVCC) does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

97-012640

301502

Exploring Manufacturing Technology

Student Edition

Table of Contents

	Page
Objective Sheet	1
Information Sheet	3
Assignment Sheet 1—Research a Manufacturing Career	9
Student Supplement 1—Examples of Some of the Careers in the Manufacturing Area	11
Assignment Sheet 2—Describe the Materials and Processes Used to Produce a Finished Manufactured Product	13
Student Supplement 2—Elements of the Methods Used to Process the Basic Industrial Materials	17
Assignment Sheet 3—Plan a Production Process	39
Student Supplement 3—Production-Process Planning	47
Lab Activity Sheet 1—Perform a Production-Process Evaluation Activity	55
Lab Activity Sheet 2—Fabricate and Test Composite Materials	65
Student Supplement 4—Composite Materials Used in Airframe Manufacturing	77
Student Supplement 5—Wing-Spar Pattern	83

Exploring Manufacturing Technology

Objective Sheet

Unit objective

After completing this unit, the student should be able to define the stages in a basic technology systems model, plan and evaluate a simple production process, and fabricate and test composite materials. The student will demonstrate these competencies by completing the assignment sheets and lab activity sheets and by scoring a minimum of 85 percent on the written test.

Specific objectives

After completing this unit, the student should be able to

1. Define the term *system*.
2. Define the term *manufacturing system*.
3. Define the term *manufacturing technology*.
4. Define the stages in a basic technology systems model.
5. Define the categories of resources essential for a manufacturing system to produce a product.
6. List the types of the basic industrial materials used in a manufacturing system.
7. Match the methods of processing the basic industrial materials used in a manufacturing system to their correct definitions.
8. Match the categories of people resources used in a manufacturing system to their correct definitions.
9. Describe the types of production processes used in manufacturing systems.
10. Match the types of automation used in manufacturing systems to their correct descriptions.
11. Research a manufacturing career. (Assignment Sheet 1)
12. Describe the materials and processes used to produce a finished manufactured product. (Assignment Sheet 2)
13. Plan a production process. (Assignment Sheet 3)
14. Perform a production-process evaluation activity. (Lab Activity Sheet 1)
15. Fabricate and test composite materials. (Lab Activity Sheet 2)

Exploring Manufacturing Technology

Information Sheet

1. **Definition of the term *system***

   - **System**—Group of people, procedures, equipment, and resources that function together to produce desired results

2. **Definition of the term *manufacturing system***

   - **Manufacturing system**—System in which materials and processes are used to produce a product that will be used elsewhere

3. **Definition of the term *manufacturing technology***

   - **Manufacturing technology**—Development of more efficient processes and materials to produce better manufactured products

4. **Stages in a basic technology systems model and their definitions**

   Note: A *systems model* is a visual representation that analyzes the stages (input, process, output, and feedback) in a technology system (see Figure 1 and Figure 2).

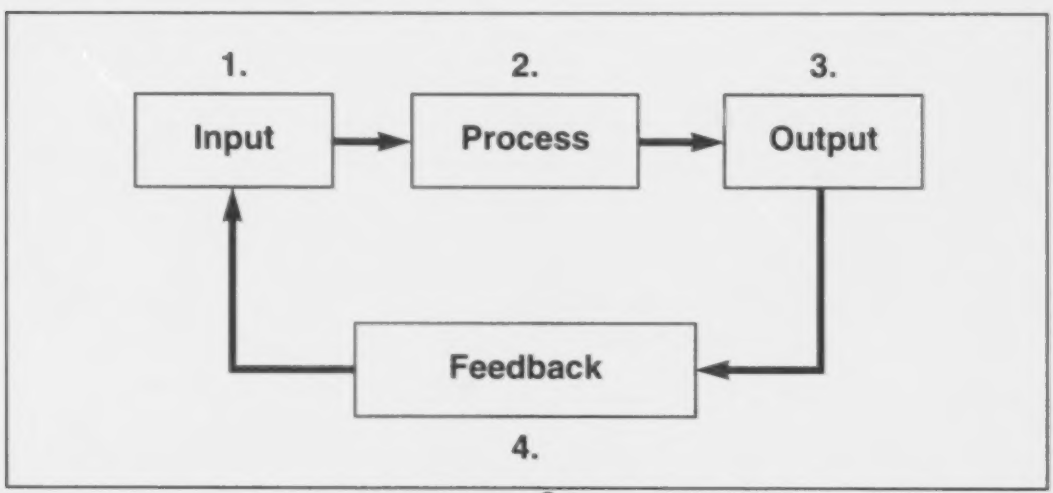
   - **Stage 1: Input**—The means by which or the point at which something is put into a system
   - **Stage 2: Process**—A series of actions or operations occurring in a system
   - **Stage 3: Output**—Something produced by a system

     Note: The output in a manufacturing system is the product produced by the system.

   - **Stage 4: Feedback**—The return to the input stage with evaluative or corrective information about the system processes and output

     Note: Feedback in a manufacturing system is provided by such things as customer response to the product, profit and losses, and quality control.

Figure 1: Universal systems model



Information Sheet

5. **Categories of resources essential for a manufacturing system to produce a product and their definitions**

   - **Financial resources** (capital)—The money needed to start and maintain the manufacturing system

   - **Materials resources**—The physical substances of which the product in the manufacturing system is made (composed)

     Note: Materials resources used to produce a product can be classified as natural or synthetic. *Natural materials* are those that exist in nature; *synthetic materials* are those that are created by people.

     Materials resources also can be classified as primary or basic industrial materials. *Primary materials* are raw materials as they are taken from the earth; logs are an example of a primary material. *Basic industrial materials* are raw materials that have been somehow processed and readied to be used in a manufacturing system; timber to be used in making furniture is an example of a basic industrial material.

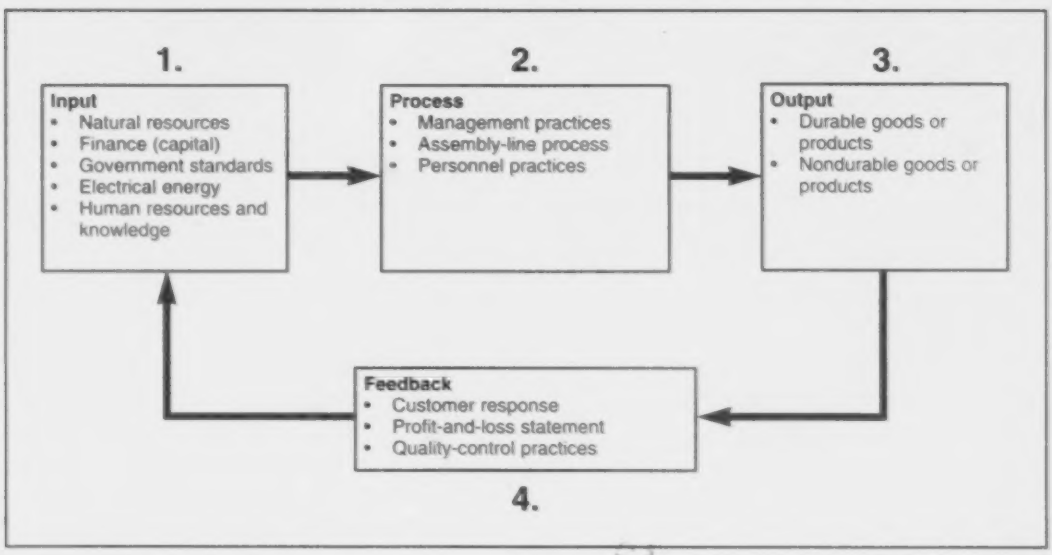
   - **People resources** (human resources)—The individuals who design, create, and control the process in the manufacturing system

   - **Facilities**—All the buildings, tools and machines (equipment), utilities, and energy resources used in the process in a manufacturing system

     Note: *Tools* and *machines* are the man-made devices or instruments that are used to extend the capabilities of people to process or maintain other resources in a manufacturing system.

     There are exhaustible and inexhaustible forms of energy. *Exhaustible* forms can be used up; *inexhaustible* forms of energy cannot be used up.

Figure 2: Universal systems model showing some of the resources used in the various stages of a basic manufacturing system



Information Sheet

6. Types of the basic industrial materials used in a manufacturing system

- **Natural materials**

  — **Woods**

  Note: Woods are natural materials composed primarily of cellulose fibers, lignin (a natural adhesive), and other substances that make up the trunk and branches of a tree. Woods do not conduct heat or electricity (making them thermal and electrical insulators), are light in weight and medium in hardness, and are used to produce products that require these properties.

  — **Metals**

  Note: Metals are durable natural materials such as iron, copper, tin, lead, aluminum, gold, and silver. Metals are good conductors of heat and electricity; can be melted, cast, and formed (see Objective 7) by pressure; are opaque but with highly reflective surfaces when polished; are durable and heavy in weight; and are used to produce products that require these properties.

  — **Earth materials**

  Note: Earth materials are non-metallic, inorganic substances extracted from the earth's crust. Examples of earth materials are clay, sand, and limestone, which are used to make products such as brick, ceramic tiles, and glass. Earth materials are hard and durable, do not conduct heat (making them thermal insulators), and are used to produce products that require these properties.

- **Synthetic materials**

  — **Plastics**

  Note: Plastics are man-made materials made from petroleum products. Plastics are light, flexible, and either soft or hard; do not conduct electricity; and are capable of being formed by heat and/or pressure. They are used to produce products that require these properties.

  — **Composites**

  Note: Bonding is a permanent assembly method in which two or more materials are combined using pressure, heat, or glue, or some other bonding agent. Man-made composites are produced by bonding two or more materials to form a new material with properties superior to the properties of the individual materials. Examples of composites are fiberglass (glass fibers embedded in a resin creating a light but strong material used in automobile bodies and many other products) and Kevlar (a light, strong, supple material used in making many products including bullet-proof vests).

Information Sheet

7. **Methods of processing the basic industrial materials used in a manufacturing system and their definitions**

   - **Separating**—Removing the excess from—changing the volume of—a material to produce a material of a desired size, shape, or finish

   - **Forming**—Changing the size and shape—but not the volume—of a material in its plastic state

     Note: *Plastic* in this sense means "capable of being molded or modeled."

   - **Casting or molding**—Pouring or forcing a material in its liquid or semiliquid state into a mold and allowing the material to solidify before removal

     Note: If a liquid or semiliquid material is poured into a mold and the mold is filled by gravity flow, the material is said to be *cast*. If a liquid or semiliquid material is pressurized and this force causes the mold to be filled, the material is said to be *molded*.

   - **Conditioning**—Treating a material with heat, cold, or chemicals to impart the material with certain desirable properties

   - **Assembling**—Combining two or more materials so that they stay together for a definite period of time

   - **Finishing**—Applying a protective or decorative finish to the surface of a base material

8. **Categories of people resources used in a manufacturing system and their definitions**

   - **Productivity personnel**

     — **Industrial engineers**—People who plan the production process, facilities (buildings, equipment, energy resources), materials, and production personnel that will be required to produce a particular product, and who conduct time and method studies to constantly improve the production process

     — **Production-control personnel**—People who purchase the materials and equipment needed in the production process, and who create schedules for the production personnel needed in the production process

     — **Industrial-relations personnel**—People who ensure positive relationships between company management, employees, and the consumers in the general public

   - **Quality-control** (QC) **personnel**—People who conduct tests and inspections to ensure that the product being produced meets certain production standards

   - **Production personnel**—People who work in any of the stages of the production process

   - **Research and development** (R & D) **personnel**—People who look at the existing product and design new ways to improve that product, or who design new products that they believe consumers will want to buy

Information Sheet

9. Types of production processes used in manufacturing systems and their descriptions

- **Custom production**—Craftsperson works alone and produces one product at a time

  Note: In custom production, automation (equipment automatically controlled by mechanical or electronic devices) is not used. Production is low and the cost per item is typically high.

  Example: Hand-made furniture production

- **Mass production** (continuous production)—Groups of workers work in a production process divided into steps and using standardized parts and components (assembly line) and automation to produce large quantities of goods

  Note: Mass production is also called *continuous production* because the standardized parts and components used in the process must be available at a continuous flow to the assembly-line workers.

  Example: Automobile production

- **Intermittent production** (batch processing)—Groups of workers work in a production process using automation to produce products in groups, lots, or batches

  Note: Intermittent production processes are used when the volume of products needed is too low to justify a continuous production process. Companies using intermittent production processes are often called *job shops* since they contract or take orders for specific jobs or quantities. Examples of companies that typically use intermittent production processes are book printers, welding shops, and machine shops.

10. Types of automation used in manufacturing systems and their descriptions

- **Robotics**—Robots are used in the production process of the manufacturing system

  Note: A robot is an "intelligent" automated machine that has sensors that link it to and allow it to be controlled by a computer. Robots are often used in the production process to perform tasks that would be too dangerous, boring, or unpleasant for a human worker to perform.

- **Computer-aided design** (CAD)—Computers are used by engineers and drafters to produce and store the drawings they create in the design stage of the manufacturing system

- **Computer-aided manufacturing** (CAM)—Computer-controlled machines are used by the production personnel in the production process of the manufacturing system

- **Computer-aided design/computer-aided manufacturing** (CAD/CAM)—Computers are used by engineers and drafters to produce and store the drawings they create in the design stage of the manufacturing system; the computer then translates the stored design into numerical data that is sent directly to computer-controlled machines used in the production process of the manufacturing system

- **Computer-integrated manufacturing** (CIM)—Computers and computer-controlled machines are used in every stage in the manufacturing system

Information Sheet

- **Flexible manufacturing system** (FMS)—Computer-controlled machines are used to make different versions of the same product on the same production line in the production process of the manufacturing system

  Note: FMSs are used most often in companies that use intermittent production processes.

- **Just-in-time** (JIT) **manufacturing**—Computer-monitored manufacturing system in which the raw materials necessary to maintain the production process are scheduled to arrive at the factory only as they are needed in the production process

  Note: JIT production processes eliminate the need for the facilities required to store the raw materials kept on hand at the factory in other types of manufacturing systems.

Exploring Manufacturing Technology

Assignment Sheet 1—Research a Manufacturing Career

Name _____ Date _____

Evaluation criteria	Rating
Directions have been followed.	_____
Research is thorough and accurate.	_____
Report is in correct format.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Introduction

In *Introduction to Technology Education,* Unit 5, "Career-Exploration Process," you learned the process for conducting career research. In this assignment sheet, you will use the skills you learned in Unit 5 to conduct career research in the manufacturing area.

Exercise

Activity checklist

Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Read** Student Supplement 1 on page 11, where examples of some of the careers in the manufacturing area are listed. You may be able to name other careers in the manufacturing area, also. **Select one career** you think you would like to explore, and **research that career**. Use the career-exploration process you learned in Unit 5 of *Introduction to Technology Education* in conducting your research.

_____ 2. **Compile the results** of your research, and prepare a **written research paper** to present the information you have compiled. A written research paper should include the following components:

- Title page
- Table of contents
- Introduction
- Body
- Conclusion
- Endnotes/footnotes

Assignment Sheet 1

_____ 3. **Turn in your research paper** to your instructor for evaluation.

_____ 4. Your instructor will return your research paper with suggestions for improvement. Make the improvements your instructor suggests, and then, **return your research paper** for **final evaluation**.

Exploring Manufacturing Technology

Student Supplement 1—Examples of Some of the Careers in the Manufacturing Area

Introduction

The following is a list of just **some** of the careers in the manufacturing area. Use this list as a beginning point in your career-exploration research process. There are many, many more careers in the ever-expanding area of manufacturing.

Productivity personnel

- Industrial engineers—People who plan the production process, facilities, materials, and production personnel that will be required to produce a particular product, and who conduct time and method studies to constantly improve the production process
- Production-control personnel—People who purchase the materials and equipment needed in the production process, and who create schedules for the production personnel needed in the production process

  Examples: Financial managers, purchasing agents, payroll personnel, accountants
- Industrial-relations personnel—People who ensure positive relationships between company management, employees, and the consumers in the general public

  Examples: Public-relations director, personnel director, training director

Quality-control personnel

- People who conduct tests and inspections to ensure that the product being produced meets certain production standards

  Examples: Quality-control engineers, lab technicians

Production personnel

- People who work in any of the stages of the production process

  Examples: Supervisors—People who oversee a major manufacturing operation in the production process

  Workers—People who control and/or perform tasks necessary to produce a product (machinists, welders, painters, etc.)

Research and development personnel

- People who look at the existing product and design new ways to improve that product, or who design new products that they believe consumers will want to buy

  Examples: Design engineers—People who are responsible for designing new products

  Lab technicians—People who are responsible for fabricating and testing designs

Exploring Manufacturing Technology

Assignment Sheet 2—Describe the Materials and Processes Used to Produce a Finished Manufactured Product

Name _____ Date _____

Evaluation criteria	Rating
Directions have been followed.	_____
Product description clearly describes the materials and processes used in creating the selected manufactured product.	_____
The terms used in Objectives 6 and 7 and in Student Supplement 2 are correctly used in the product description.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Introduction

In Objective 6 of the information sheet, you studied the basic industrial materials used in manufacturing:

- Woods
- Metals
- Earth materials
- Plastics
- Composites

In Objective 7, you studied the methods used to process the basic industrial materials used in manufacturing:

- Separating
- Forming
- Casting (molding)
- Conditioning
- Assembling
- Finishing

In this assignment, you will read Student Supplement 2, where you will learn more about the methods used to process the basic industrial materials. Then, you will identify five manufactured products around your home and describe one of those products.

Completing this exercise will help you to better understand how the basic manufacturing processes are used to produce the manufactured products you use in your everyday life.

Assignment Sheet 2

Exercise

Part A **Select the finished manufactured product you will describe.**

Activity checklist Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Read** Objectives 6 and 7 in the information sheet.

_____ 2. **Read Student Supplement 2**, "Elements of the Methods Used to Process the Basic Industrial Materials," which begins on page 17.

_____ 3. **Select** five finished manufactured products you use in your home everyday. These should be very simple products made of only a few visible components. You will be describing one of these five products to complete Part B in this assignment sheet.

Write these five products in a list on a separate sheet of paper, and label this paper "Product List."

_____ 4. **Turn in** your product list to your instructor.

_____ 5. Your instructor will return your product list with suggestions for improvement. Make the improvements your instructor suggests.

_____ 6. Select one product from your product list and research the basic industrial materials used to manufacture the components of the product and the methods used to process those basic industrial materials.

Part B **Describe the manufactured product.**

Activity checklist Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Read** the "Analysis Check" on the next page.

_____ 2. On a separate piece(s) of paper, **describe** the finished manufactured product you selected and researched in Part A above. In your description, you must complete all the items presented in the "Analysis Check."

Label this paper "Product Description."

_____ 3. **Turn in** your "Product Description" to your instructor for evaluation.

_____ 4. Your instructor will return your "Product Description" with suggestions for improvement. **Make the improvements** your instructor suggests, and then, **return your description** to your instructor for **final evaluation**.

Assignment Sheet 2

Analysis Check

Complete each item below to describe the finished manufactured product you have selected.

1. Make a drawing (or drawings) of the manufactured product that clearly shows the visible components of the product. Label each of the visible components on your drawing(s).

2. Describe the basic industrial material(s) that was used to produce each of the visible components of the product. Use the terms used in Objective 6 in the information sheet in your description.

3. Describe which of the method(s) used to process industrial materials (separating, forming, casting, conditioning, assembling, finishing) was used to produce each of the visible components of the product. Use the terms used in Objective 7 of the information sheet and in Student Supplement 2 in your description.

4. Describe the methods used to assemble the components and finish the product. Use the terms used in Objective 7 of the information sheet and in Student Supplement 2 in your description.

Exploring Manufacturing Technology

Student Supplement 2—Elements of the Methods Used to Process the Basic Industrial Materials

Terms and definitions associated with materials processing

- **Finished product**—The product produced in a production process; a product that has been completely assembled and is ready for the consumer
- **Component**—A portion of a finished manufactured product; a portion that requires no further processing except assembly
- **Assembly**—Process of combining the components of a product
- **Plastic**—Capable of being molded or modeled

Separating

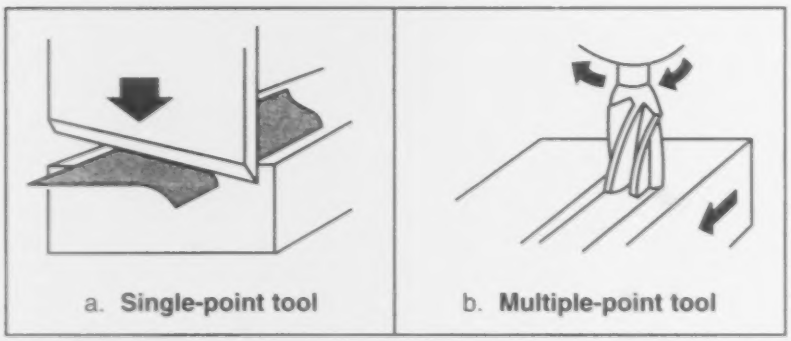
Removing the excess from—changing the volume of—a material to produce a material of a desired size, shape, or finish

The process of separating a material can be broken down into three elements: (1) the cutting tool, (2) the feed/cutting motion, and (3) the support or clamp.

- **Cutting tool**

  The tool used to separate materials can be either a traditional cutting tool with a single point (such as a shear) or a multiple point (such as a drill) (see Figure 1); or it can be a nontraditional tool that uses electrical arcs, chemical action, or heat or flame to separate the material. Electrical-discharge machining (EDM), chemical milling, and laser-beam machining are examples of separation processes using nontraditional cutting tools.

  Figure 1: Traditional cutting tools



a. **Single-point tool** b. **Multiple-point tool**

- **Feed/cutting motion**

  The feed/cutting motion refers to the movement between the cutting tool and the material being separated. The **feed motion** is the movement that brings the cutting tool in contact with the material to be separated; the **cutting motion** is the movement used to actually separate the material. Cutting motions can be classified as a rotary (turning) motion, a reciprocating (back-and-forth or up-and-down) motion, or a linear (straight-line) motion.

- **Support or clamp**

  Vises, clamps, hold-downs, and other types of devices are used to ensure a more accurate cut by holding in place either the material to be cut or the cutting tool.

The three elements of separating—cutting tool, feed/cutting motion, and support or clamp—are always present in some form in a separating process. However, these elements may vary from one type of separating process to another and may be used in different combinations. For example, in sawing (see the section below) with a circular saw, the cutting tool (blade) rotates (cutting motion) through the material (feed motion); with a scroll saw or hand saw, the blade reciprocates (cutting motion) through the material (feed motion); and with sawing machines, the material is moved past (feed motion) the blade as it rotates (cutting motion).

There are nine categories of separating processes that incorporate the three elements listed above—seven that use a traditional cutting tool and two that use a nontraditional cutting tool.

The processes that use a traditional cutting tool are (1) sawing, (2) shearing, (3) turning, (4) abrading, (5) milling, (6) shaping, and (7) drilling.

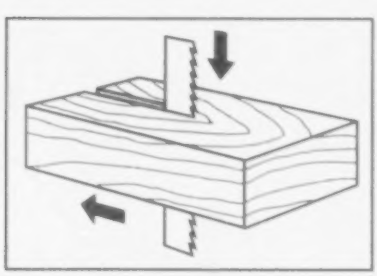
The processes that use a nontraditional cutting tool are (1) separation by heat or acids and (2) induced-fracture separation.

- **Separation processes that use a traditional cutting tool**

  1. **Sawing**—Separating material with a cutting tool that has pointed teeth equally spaced along the edge of a blade (see Figure 2)

     A hacksaw that is used to saw metal is an example of a hand tool that uses this separation process; a circular saw that is used to saw wood is an example of a power tool that uses this type of separation process.

     Figure 2: Sawing

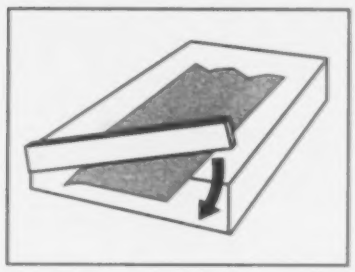
     

  2. **Shearing**—Separating material with a cutting tool that uses two cutting edges that cross one another to separate the material, or that uses a single cutting edge that is forced through the material to be separated (see Figure 3)

     Scissors are an example of a hand tool that uses a shearing separation process; a metal-cutting shear and a metal-punching machine are examples of power tools that use this type of separation process.

Student Supplement 2

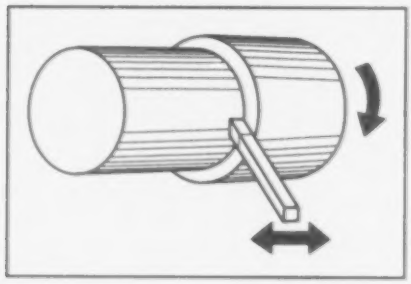
Figure 3: Shearing



3. **Turning**—Separating material by revolving the material to be separated against a fixed cutting tool with a single edge (see Figure 4)

   A lathe is an example of a tool that separates material by turning.

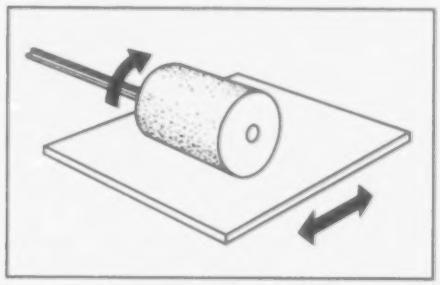
Figure 4: Turning



4. **Abrading**—Separating material by using a cutting tool that wears away the material, usually by the action of mineral particles on the cutting-tool surface (see Figure 5)

   Sanding and grinding, water-jet machining, and sand blasting are examples of this type of separating process.

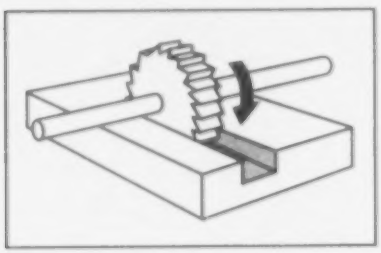
Figure 5: Abrading



5. **Milling**—Separating material with a cutting tool that has sharpened teeth equally spaced around a cylinder or along a flat surface (see Figure 6)

   A file is an example of a hand tool that uses milling in the separation process. Power milling machines that mill metal and power planers, surfacers, joiners, and shapers that mill wood are examples of power tools that use milling in the separation process.

   Figure 6: Milling

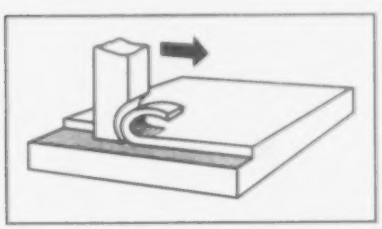


6. **Shaping**—Separating material by moving a single-edged cutting tool in a straight-line cutting motion across a fixed workpiece (material to be separated) (see Figure 7)

   A hand-held planer is a hand tool that is used in a shaping separation process. A metal shaper is a power tool that is used in a shaping separation process.

   Note: A machine called a *shaper* is given as an example of a power tool used in a milling process. Just because a machine is called a *shaper*, does not mean that a hand or power tool separates with a *shaping process*. Understanding the elements a tool uses in the separation process is the key to understanding the true nature of that separation process.

   Figure 7: Shaping

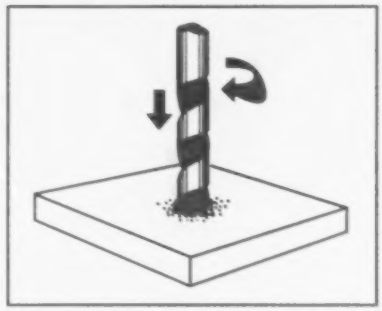


7. **Drilling**—Separating material by using a cutting tool with two rotating cutting edges that form or enlarge a hole in the material to be separated (see Figure 8)

   A drill press is an example of a power tool that uses drilling in the separation process.

Student Supplement 2

Figure 8: Drilling

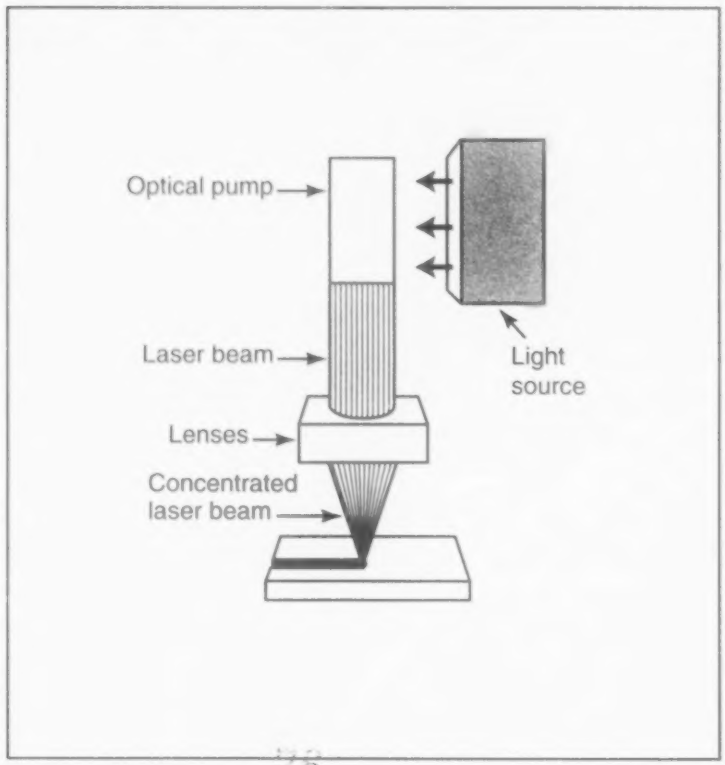


- **Separation processes that use a nontraditional cutting tool**

  1. **Separation by heat or acid**—Separating material using electrical, electro-chemical, chemical, or thermal erosion (heat or acid-based) cutting techniques

     Laser-beam machining (see Figure 9), electrical-discharge machining (EDM), flame-cutting (oxyacetylene cutting), and chemical milling are all examples of separation by heat or acid processes.

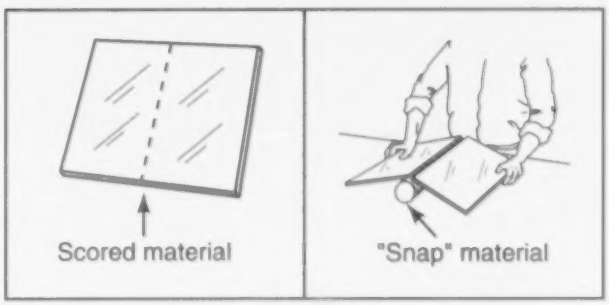
Figure 9: Laser-beam machining



2. **Induced-fracture separation**—Separating material using a cutting tool to score a line (make a shallow cut or scratch) in the material to be separated, and then, breaking the material along this line (see Figure 10)

   Cutting glass with a hand-held glass cutter is an example of an induced-fracture separation process.

   Figure 10: Induced-fracture separation process



Forming **Changing the size and shape—but not the volume—of a material in its plastic state**

The process of forming usually involves heating a material to its plastic state, placing the plastic material in or around a forming device, and applying pressure so that the plastic material conforms to the shape of the forming device. The process of forming, therefore, can be broken down into three elements: (1) forming device, (2) forming temperature, and (3) source of forming pressure.

- **Forming devices**

  Dies and rolls are the two types of devices used to form materials. **Dies** are devices made from hardened substances that have been shaped so as to determine the final shape of the material to be formed. There are three types of dies: (1) open, (2) mated (closed), and (3) one-piece shaped.

  1. **Open dies** are the simplest type of die; they consist of two mold parts—one part that moves and one part that is stationary. Using a hammer (moving part) to form a piece of metal over an anvil (stationary part) is an example of an open-die forming device.

  2. **Mated dies** (closed dies) consist of two mold parts that have been machined to a desired shape. The forming process is completed by forcing a material into the shape formed when the two halves of the mold are closed.

  3. **One-piece shaped dies** are made of a hardened substance that has been shaped; the material to be formed is then either formed around or forced into or through the die to determine the final shape of the solidified material.

Student Supplement 2

A **roll** is a cylinder. Rolls used as forming devices are smooth or shaped cylinders often linked in a series. The material to be formed is either forced into or formed around this series of cylinders. Metal being forced through a series of rolls to form flat metal sheets is an example of a forming process using rolls.

- **Forming temperature**

The *forming temperature* of a material has to do with the temperature range in which a material can be formed without causing internal stress to the material (when it is in a *plastic* state). Generally, the softer (and usually the hotter) the material, the less pressure is required to form the material (see the section on forming pressure below).

In a **hot-formed** process, the material is heated to the hottest temperature at which it can be formed without causing internal stress to the material. A hot-formed process allows the material to be formed using a lower forming pressure without changing the hardness of the resulting product. Hot-rolled steel (HRS) is an example of a product formed with a hot-formed process.

In a **cold-formed** process, the material is cooled to the lowest temperature at which it can still be formed without causing internal stress to the material. For some materials, this temperature is room temperature, but other materials may have to actually be heated to reach this temperature. The products resulting from a cold-forming process have smoother finishes, improved strength, a tighter grain structure, greater hardness, and improved dimensional accuracy. Cold-rolled steel (CRS) is an example of a product formed with a cold-formed process.

Some materials, such as clay, are in a plastic state at room temperature and, therefore, do not have to be heated or cooled in order to be formed. Many wood products do not have to be heated or cooled in order to be plastic; wood can be softened by steam, which allows it to be shaped to the proper form.

- **Forming pressure**

Forming pressure is the amount of pressure required to form the plastic material into the desired shape. Forming pressure is achieved with many different types of devices, depending on the material to be shaped. With some materials, all the pressure that is required can be achieved using hand tools (hammers and hand-operated presses, for example). Other materials require more pressure to form the material into the desired shape. For these materials, power equipment is used. For example, powered rolling machines create the pressure required to roll sheet steel; draw benches are used to stretch metal and form wire; air pressure or vacuum pressure is used to form plastic; and explosive forming and electromagnetic forming are used to form metal.

Student Supplement 2

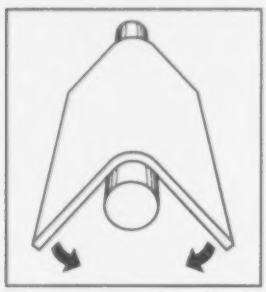
- **Forming processes**

There are nine basic types of forming processes: (1) bending, (2) extrusion, (3) pressing, (4) rolling, (5) drawing, (6) forging, (7) blow molding, (8) thermoforming, and (9) high-energy rate forming (HERF). However, there are many other forming processes that are specific to the material they are used to form.

1. **Bending**—Straining a plastic material uniformly around a die or a straight axis (see Figure 11)

   Bending sheet metal over a bar folder is an example of a bending forming process.

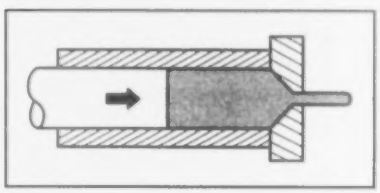
   Figure 11: Bending



2. **Extrusion**—Forcing a plastic material from a closed chamber through a die opening that controls its cross-sectional shape (see Figure 12)

   Squeezing toothpaste from its container is a basic example of an extrusion forming process; creating plastic pipe is a much more complex extrusion forming process, but it uses the same principle.

   Figure 12: Extrusion

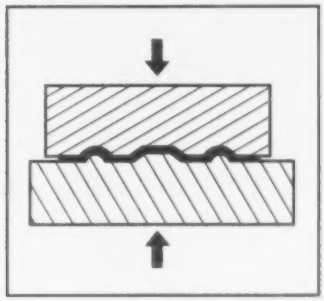


3. **Pressing**—Squeezing a plastic sheet material between two dies to form a desired shape (see Figure 13)

   The process used to emboss metal license plates is an example of a pressing forming process.

Student Supplement 2

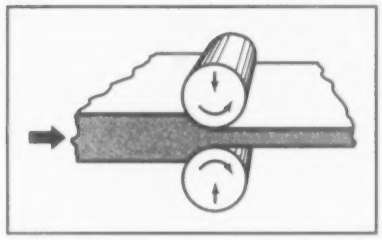
Figure 13: Pressing



4. **Rolling**—Squeezing a plastic material between rotating rollers to produce sheets or plates (see Figure 14)

   In a rolling forming process, the material that is rolled typically decreases in thickness but increases in length. Rolling sheet metal, calendering paper and plastics, and rolling out pie dough are all examples of a rolling forming process.

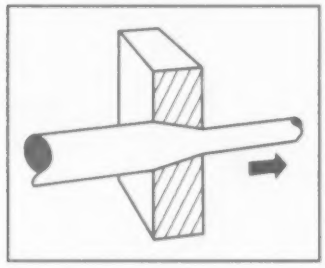
Figure 14: Rolling



5. **Drawing**—Pulling a plastic material through a series of dies that are progressively reduced in cross-sectional area, therefore reducing the cross-sectional area of the plastic material and increasing its length (see Figure 15)

   The process used to form copper wire is an example of drawing.

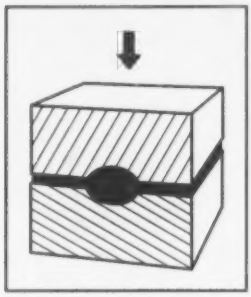
Figure 15: Drawing



6. **Forging**—Using compressive force on a plastic material to form it to a desired shape (see Figure 16)

   Applying blows to a piece of metal with a hammer and drop-forging a screwdriver blade are both forms of forging.

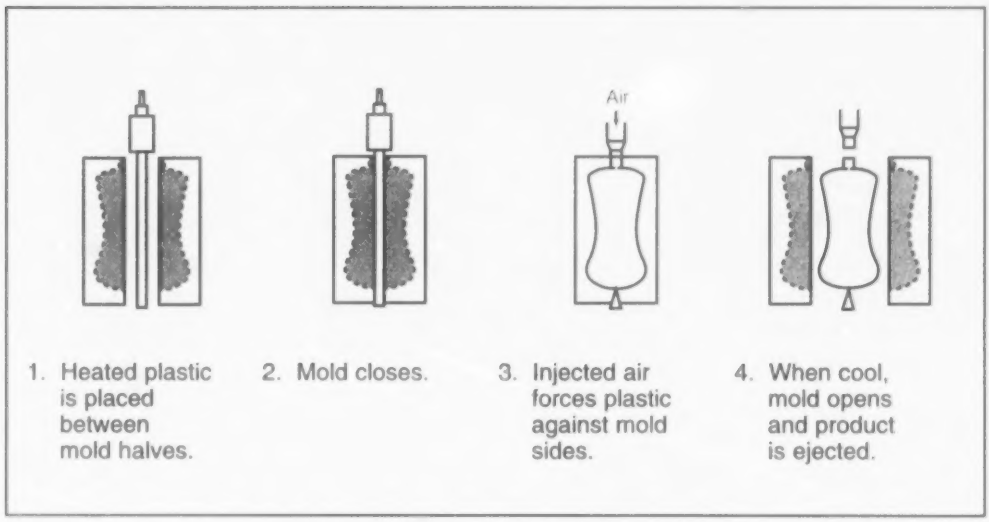
Figure 16: Forging



7. **Blow molding**—Trapping a plastic material in a mold, and then using air pressure to force the plastic material to form to the internal shape of the mold (see Figure 17)

   Plastic milk bottles are formed using a blow-molding process.

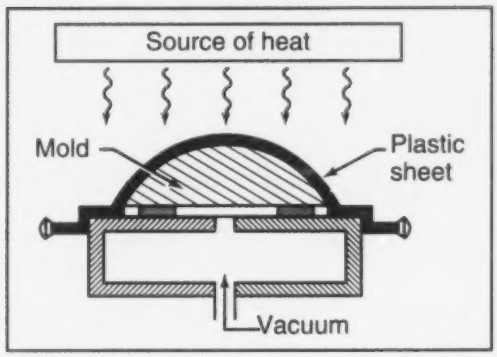
Figure 17: Blow molding


Air
1. Heated plastic is placed between mold halves.
2. Mold closes.
3. Injected air forces plastic against mold sides.
4. When cool, mold opens and product is ejected.

8. **Thermoforming**—Using air pressure, vacuum pressure, or mechanical force on a plastic sheet material to form the material to the contour of a mold (see Figure 18)

   Plastic signs are often made by applying vacuum pressure to form the heated plastic to the contour of a mold.

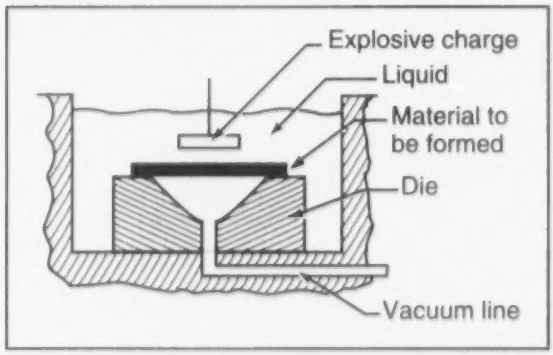
Figure 18: Thermoforming



9. **High-energy-rate forming** (HERF)—Using some form of high-energy-rate force (detonated explosives or electromagnets, for example) to force a plastic material into the shape of a die (see Figure 19)

   Metal parts are sometimes created by an explosive forming process.

Figure 19: HERF



Casting or molding

Pouring (casting) or forcing (molding) a material in its liquid or semi-liquid state into a mold and allowing the material to solidify before removal

The process of casting or molding a material can be broken down into five elements: (1) creating the mold, (2) preparing the material for casting or molding, (3) introducing the material into the mold, (4) solidifying the material in the mold, and (5) removing the solidified material (casting) from the mold.

- **Creating the mold**

  The first step in a casting or molding process is creating the mold. Three types of molds are used in a casting or molding process: (1) one-shot molds, (2) permanent molds, and (3) cores.

1. **One-shot molds**—Molds that are typically made of sand and binders or of plaster; this type of mold is used only one time and then is disposed of

   The green-sand mold used in pouring aluminum is an example of a one-shot mold.

2. **Permanent molds**—Molds that can be used over and over in either a molding or casting process; these molds are typically made out of materials with very high melting temperatures and with the capability of withstanding the effects of the heat and pressure required in the molding or casting process

3. **Cores**—Types of molds used to create hollow passages or openings in materials that are to be cast or molded; with this type of mold, the material to be cast or molded flows around the cores and the cores are removed once the material has solidified

- **Preparing the material for casting or molding**

To be cast or molded, the material must be in a liquid or semiliquid state. Three methods are used to transform a material to a liquid or semiliquid state: (1) dissolving the material, (2) melting the material, and (3) compounding the material.

1. In **dissolving a material**, solvents are added to the material to make the material liquid or semiliquid. For example, clay is made into the liquid "slip" used in casting by adding water to the clay.

2. In **melting a material**, heat is applied to a material until it reaches a liquid or semiliquid state. For example, the lead used to make "sinkers" is heated to a liquid state and then poured into a permanent mold.

3. In **compounding a material**, additives are mixed with the material to form a liquid or semiliquid compound. For example, to produce a chess piece, colorants (coloring agents) and a catalyst are compounded with polyester resin, and then, this liquid compound is poured into a rubber mold.

- **Introducing the material into the mold**

The material to form a casting is introduced into a mold by one of two methods: (1) casting or (2) molding.

If a liquid or semiliquid material is poured into a mold and the mold is filled by gravity flow (gravity-poured), the method of introduction is called **casting**. Pouring slip into a sand mold is an example of casting.

If a liquid or semiliquid material is pressurized and this force causes the mold to be filled, the method of introduction is called **molding**. The injection-molding process used to shape plastics is an example of molding.

Student Supplement 2

- **Solidifying the material in the mold**

  To *solidify* a material means to allow it or force it to harden. In a casting or molding process, a material is solidified by (1) drying, (2) chemical action, or (3) cooling.

  1. In **drying**, the liquid or semiliquid material in the mold is allowed to evaporate without the addition of heat, therefore, forming a solid material. To produce some products, the liquid or semiliquid material is allowed to evaporate naturally, while to produce other products, the evaporation process is speeded up by adding solvents to the material.

     For example, to create a hollow clay casting, liquid slip is poured into a plaster mold. The plaster mold absorbs the water from the slip, causing the casting's outer surface to dry. The remaining liquid slip is then poured out of the mold, creating the hollow casting. However, to create some plastic films, liquid plastic is suspended in a solvent and the resulting liquid is then poured out on a very smooth surface. The solvent in the liquid quickly evaporates, leaving a thin layer of solid plastic.

  2. When heat is given off by a liquid or semiliquid material as it solidifies, it is said to have solidified by **chemical action**. The process used to cast plastic resins such as water-extended polyester (WEP) is an example of chemical action.

  3. When a liquid or semiliquid material such as liquid metal or a thermoplastic is **cooled** to a temperature well below its melting temperature, it hardens as it solidifies. This cooling process is also called *hardening*.

- **Removing the solidified material (casting) from the mold**

  The solidified material (casting) created in a casting or molding process is removed from the mold in one of two ways: (1) opening the mold or (2) destroying the mold.

  1. A permanent mold is **opened** and the casting removed so that the mold can be saved and used over and over again. The permanent molds used in casting ceramics are examples of molds that are opened and then saved for future casting processes.

  2. A one-shot mold is **destroyed** when the casting is removed. A sand-cast mold is an example of a one-shot mold that is destroyed when the casting is removed.

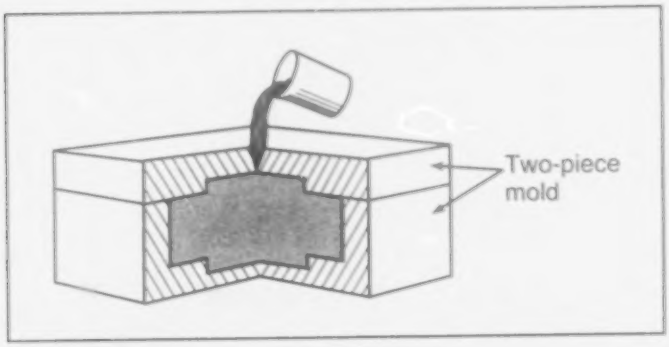
- **Casting processes**

  There are eight basic casting processes that can be divided into three categories: (1) casting solid objects, (2) casting hollow objects, and (3) casting objects while using rotational or centrifugal force.

Student Supplement 2

Four processes are used to **cast solid objects** (see Figure 20): (1) sand casting, (2) investment casting, (3) permanent molding, and (4) dip casting.

Figure 20: Casting solid objects



1. **Sand casting**—Casting process in which a liquid or semiliquid material is poured into a mold made of aggregate material (sand); when the liquid or semiliquid material solidifies, the mold is destroyed in order to remove the casting. Green-sand casting is an example of a sand-casting process.

2. **Investment casting**—Casting process in which a wax or low-temperature plastic pattern is placed inside a mold; after a liquid or semiliquid material is poured into the mold, the pattern vaporizes, allowing the liquid or semiliquid material to occupy the space in the mold that had been occupied by the pattern

   Lost-wax processes used for making jewelry and dental work and lost-foam processes used for making engine parts are examples of investment casting.

3. **Permanent molding**—Casting process in which a liquid or semiliquid material is poured into a permanent mold

   A permanent-molding process is used when aluminum or steel molds are used to cast concrete planters.

4. **Dip casting**—Casting process in which a mold is dipped into liquid or semiliquid material and the cast is formed as the material solidifies on the outside of the mold

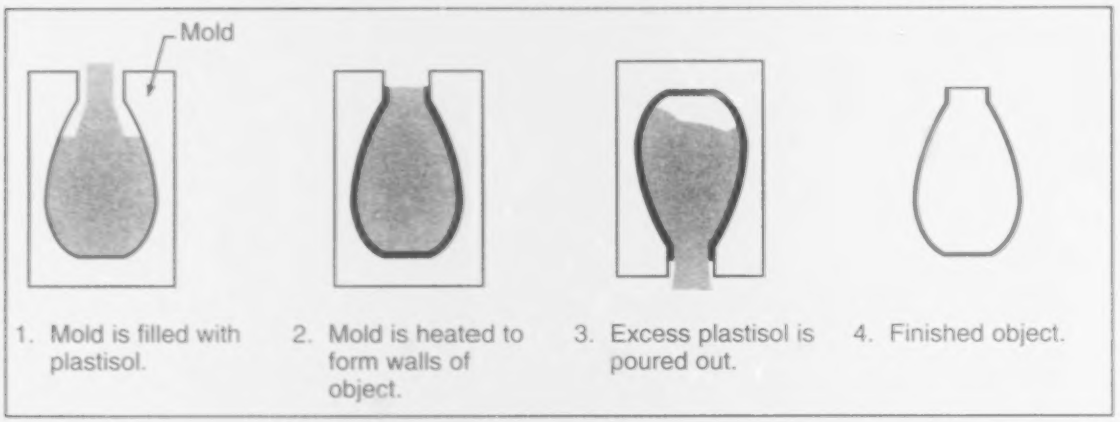
   A dip-casting process is used to produce plastic surgical gloves.

Two processes are used to **cast hollow objects**: (1) slush casting and (2) slip casting. In both of these processes, a liquid or semiliquid material is poured into a mold and allowed to begin the solidification process, then excess material is poured out of the mold, leaving behind a hollow casting (see Figure 21).

Student Supplement 2

Slush casting is used to make hollow castings from metal and plastic materials; slip casting is used to make hollow castings from clay materials.

Figure 21: Casting hollow objects


Mold
1. Mold is filled with plastisol.
2. Mold is heated to form walls of object.
3. Excess plastisol is poured out.
4. Finished object.

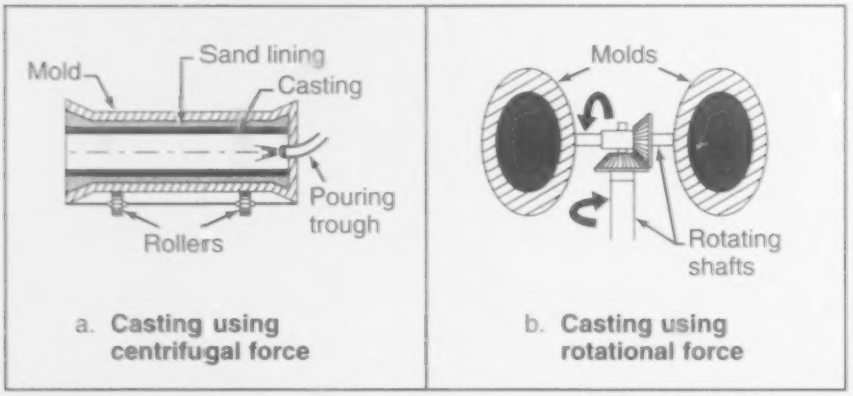
Two casting methods use the forces created by motion to aid in the casting process: (1) centrifugal casting and (2) rotational casting (see Figure 22).

1. **Centrifugal casting**—Casting process in which a liquid or semiliquid material is poured into a mold, and then centrifugal force is applied to the mold to force the material against the mold wall and into the mold cavities

   The spin-casting process used in casting belt buckles is an example of centrifugal casting.

2. **Rotational casting**—Casting process in which liquid or semiliquid material is poured into a mold, and then rotational force is applied to two axes of the mold to force the material against the wall of the mold

Figure 22: Centrifugal and rotational casting

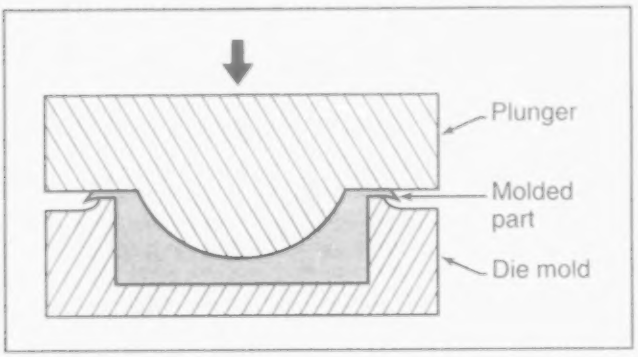


- **Molding processes**

There are two types of molding processes: (1) compression molding and (2) injection molding.

1. **Compression molding**—Molding process in which a liquid or semiliquid material is forced into a mold by compression (see Figure 23)

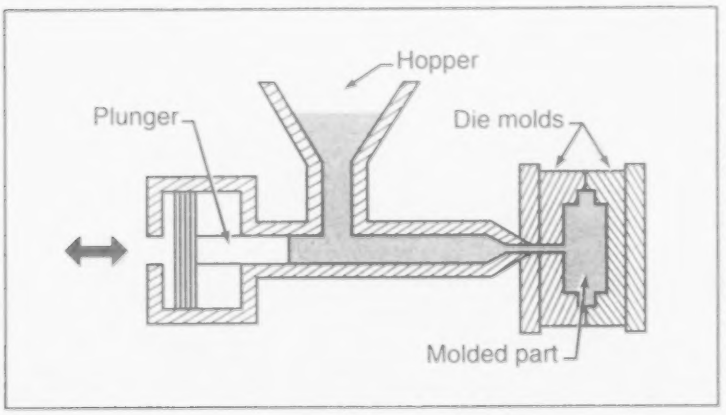
Figure 23: Compression molding



2. **Injection molding**—Molding process in which a liquid or semiliquid material is injected into a mold (see Figure 24)

Injection molding is used to produce many plastic products.

Figure 24: Injection molding



Conditioning **Treating a material with heat, cold, or chemicals to impart the material with certain desirable properties**

Materials are conditioned for three reasons:

1. To make the material easier to form or separate, such as when aluminum is heat-treated to soften it so that it is easier to cut;

Student Supplement 2

2. To remove internal stress created by the manufacturing process, such as when welded metal parts are heat-treated to keep them from cracking or distorting;

3. To impart the material with certain desirable properties (hardness, ductility, toughness, strength, stiffness, etc.), such as when copper is "peened" to make it stiffer and harder.

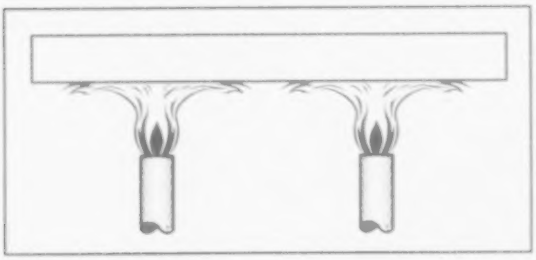
There are three types of conditioning processes: (1) thermal conditioning, (2) chemical conditioning, and (3) mechanical conditioning.

- **Conditioning processes**

1. **Thermal conditioning**—Conditioning process in which heat is applied to a material to improve the properties of the material (see Figure 25)

   Drying (seasoning) wood, heat-treating metal, and firing ceramics are examples of thermal conditioning.

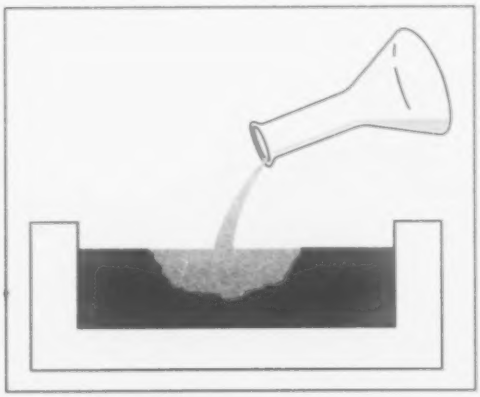
   Figure 25: Thermal conditioning



2. **Chemical conditioning**—Conditioning process in which a chemical is added to a material to improve the properties of the material (see Figure 26)

   Adding yeast to bread dough to make it softer and adding manganese to molten steel to make it stronger are two examples of chemical conditioning.

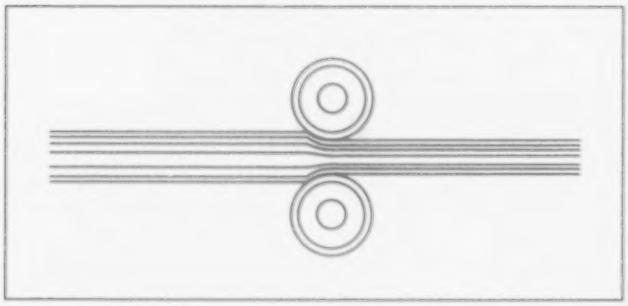
   Figure 26: Chemical conditioning



3. **Mechanical conditioning**—Conditioning process in which a material is pounded or squeezed to improve the properties of the material (see Figure 27)

   Pounding a steak to break the tough connecting fibers and make the steak more tender and compressing wood to make it take up less space but remain strong are both examples of mechanical conditioning.

Figure 27: Mechanical conditioning



Assembling

Combining two or more materials so that they stay together for a definite period of time

The assembling process can be broken down into two elements: (1) mechanical fastening and (2) bonding.

- **Mechanical fastening**

  There are two types of mechanical fastening: materials are held together either (1) by mechanical force or (2) by mechanical fasteners.

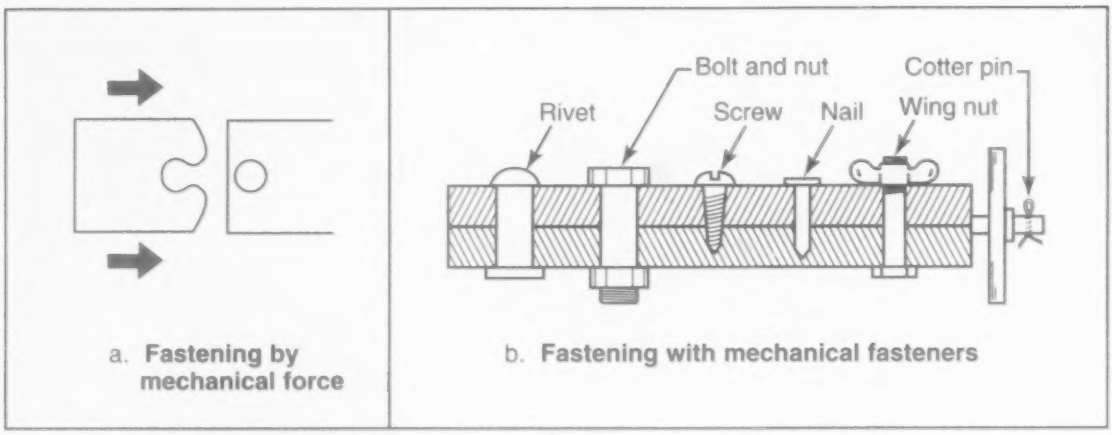
  1. **Mechanical force**—Mechanical fastening that occurs when two or more materials are forced together (see Figure 28-a)

     Materials that are "shrink-fitted," "snap-fitted," and "press-fitted" are examples of fastening by mechanical force. To "shrink-fit" an insert into plastic, for instance, the insert is put in the plastic material immediately after the material has been placed in a mold, and then, the plastic cools, solidifies, and contracts (shrinks) around the insert.

  2. **Mechanical fasteners**—Mechanical fastening that occurs when a device is used to hold two or more materials together permanently, semi-permanently, or temporarily (see Figure 28-b)

     Sewing, weaving, and rivets are examples of permanent mechanical fasteners; nails, screws, bolts, and staples are examples of semi-permanent mechanical fasteners; and cotter pins, clips, wing nuts, and safety pins are examples of temporary mechanical fasteners.

Figure 28: Mechanical fastening



a. **Fastening by mechanical force**

b. **Fastening with mechanical fasteners**

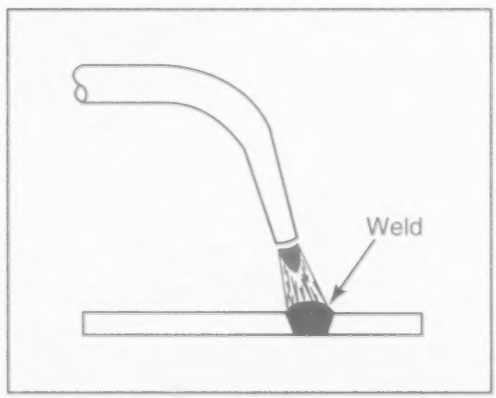
- **Bonding**

Bonding is a permanent assembly process in which two or more materials are permanently combined using pressure, heat, glue, or some other bonding agent. Two types of bonding processes are used in manufacturing: (1) cohesive bonding and (2) adhesive bonding.

1. **Cohesive bonding**—Process of permanently fusing (intermingling the molecules of) two or more like materials by melting or softening the materials through the use of heat, pressure, or a solvent

   Welding metals (see Figure 29) and fusing like plastics with a solvent are examples of cohesive bonding.

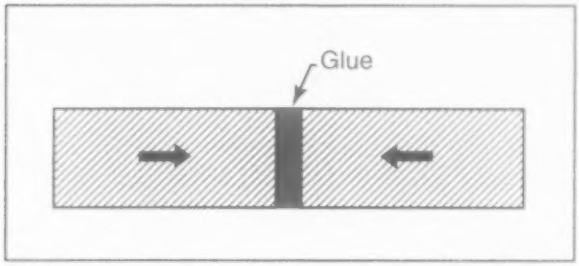
   Figure 29: Cohesive bonding two metals by welding



2. **Adhesive bonding**—Process of using glue or cement to adhere the surfaces of two or more like or unlike materials (to hold the surfaces of two or more like or unlike materials together without an intermingling of their molecules)

Fastening two pieces of wood with glue (see Figure 30), using contact cement to fasten plastic laminate to a wood cabinet top, holding bricks or stone together with mortar, and attaching a coupling to a copper pipe with solder are all examples of adhesive bonding.

Figure 30: Adhesive bonding two pieces of wood with glue



Finishing

Applying a protective or decorative finish to the surface of a base material

The finishing process can be broken down into three elements: (1) selecting the appropriate finishing material or method for the base material, (2) preparing the surface of the base material for the finishing material or method, and (3) applying the finishing material or method to the surface of the base material.

- **Selecting the appropriate finishing material or method for the base material**

  Three options can be used to finish a base material. Two of these options—converted coatings and coatings—involve applying a material to the outer surface of the base material; the third option involves altering the appearance of the surface of the base material.

  1. With a **coating**, a layer of another material is applied to the surface of the base material. Applying a chrome plating to a metal surface and applying a coating of paint to a wood surface are examples of applying a coating to the surface of a base material.

  2. With a **converted coating**, a layer of another material (a coating—usually a chemical) is applied to the surface of the base material, and the coating changes the surface of the material into a new material. Anodizing aluminum and blueing a gun are examples of converted coatings.

  3. In **altering the appearance of the surface of the base material**, no coating is added to the surface of the base material. The surface of the base material is itself changed. Sandblasting metal to produce a textured finish is an example of altering the appearance of the surface of the base material.

Student Supplement 2

- **Preparing the surface of the base material for finishing**

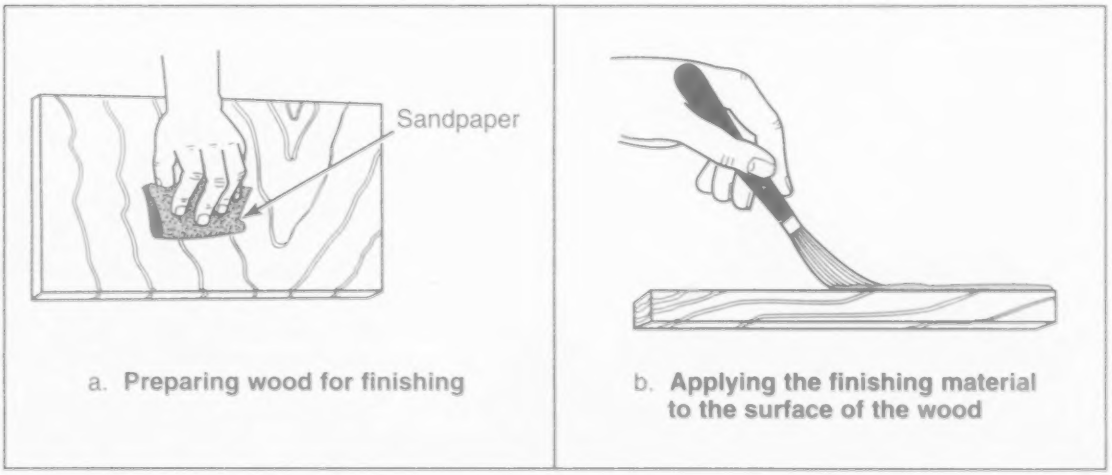
  Preparing the surface of a base material for finishing usually involves either smoothing or cleaning the surface. Two methods are used for this preparation process: (1) mechanical preparation methods and (2) chemical preparation methods. Examples of **mechanical preparation methods** are sanding wood surfaces (see Figure 31-a) and blasting or burnishing metal surfaces. An example of a **chemical preparation method** is "pickling," applying mild acids to a wood surface.

- **Applying the finishing material or method to the base material**

  Three methods can be used to apply a finishing material to the surface of a base material: (1) chemical application methods, (2) electrical application methods, and (3) mechanical application methods (see Figure 31-b). As you learned in the previous section, if the material that is applied adheres to the surface of the base material, it is called a *coating*; if the material changes the surface of the base material into a new material, it is called a *converted coating*. Chemical and electrical application methods are usually associated with converted coatings; however, all three application methods are often combined to achieve a desired finish.

  1. **Chemical application method**—A chemical is applied to the surface of the base material
  2. **Electrical application method**—Electrical current is used to deposit a finishing material on the surface of the base material
  3. **Mechanical application method**—Some mechanical means is used to apply a finishing material to the surface of the base material

Figure 31: Finishing a wood surface



a. **Preparing wood for finishing**

b. **Applying the finishing material to the surface of the wood**

Exploring Manufacturing Technology

Assignment Sheet 3—Plan a Production Process

Name _____ Date _____

Evaluation criteria	Rating
Directions have been followed.	_____
The analysis completed in Part A is neat and thorough and shows an understanding of the methods used to process the basic industrial materials.	_____
Completed charts and diagrams for the production process meet the criteria of the key principles of production-process planning that are presented in Student Supplement 3.	_____
Completed charts and diagrams are neat, complete, and accurate.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Introduction

In Objective 7 of the information sheet, you studied the methods used to process the basic industrial materials used in manufacturing:

- Separating
- Forming
- Casting (molding)
- Conditioning
- Assembling
- Finishing

In Assignment Sheet 2 and Student Supplement 2, you learned more about the processes used to produce finished manufactured products. Have you ever thought of pizza as a manufactured product? The frozen pizza you buy at the grocery store is a manufactured product mass-produced in factories, and to make pizzas, the factory workers use all of the manufacturing processes you learned about in Objective 7 and in Assignment Sheet 2 and Student Supplement 2.

The pizza you buy at a local pizza place is also a manufactured product, and to make pizzas, the workers at a pizza place also must use all of the manufacturing processes you learned about in Objective 7 and in Assignment Sheet 2 and Student Supplement 2.

Assignment Sheet 3

In this assignment sheet, you will take a basic recipe for pizza and analyze it. By completing this product-process analysis exercise, you will better understand the methods used to process the basic materials as these processes apply to all manufacturing technologies.

Exercise

Part A **Analyze the processes used in manufacturing a pizza.**

Activity checklist Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Review Objective 7** in the information sheet.

_____ 2. **Review Student Supplement 2**, "Elements of the Methods Used to Produce the Basic Industrial Materials."

_____ 3. **Read** the complete **recipe** for making one pizza on the following pages. Then, **analyze** the recipe as to the processes that would be used to manufacture the pizza: on the blank line provided after each step in the recipe, identify which method (separating, forming, casting or molding, conditioning, assembling, or finishing) would be used to complete that step.

_____ 4. **Turn in** the completed recipe analysis to your instructor.

_____ 5. Your instructor will return your recipe analysis with suggestions for improvement. Make the improvements your instructor suggests, and then, **return your recipe analysis** to your instructor for **final evaluation**.

Assignment Sheet 3

Pizza Recipe

A. **Prepare pizza sauce.**

Ingredients: One 15-ounce can of tomato sauce

Italian seasoning:
- 1 tsp. thyme
- 1 tsp. marjoram
- 1 tsp. oregano
- 1 tsp. parsley

Directions:		Process used:
Step 1	Measure ingredients.	
Step 2	Combine ingredients in a sauce pan.	
Step 3	Cover and simmer at low heat, stirring occasionally, until sauce is thick (approximately 30 minutes).	

B. **Prepare pizza crust.**

Ingredients: 3 cups flour (sifted)
1 ½ tsp. salt
¼ tsp. pepper
1 pkg. yeast
1 cup water or milk
1 T. shortening

Directions:		Process used:
Step 1	Measure ingredients.	
Step 2	Combine ingredients in mixing bowl and stir until evenly moist.	
Step 3	Shape dough into a ball.	
Step 4	Knead dough for 3 to 4 minutes.	
Step 5	Place dough in a greased bowl.	
Step 6	Cover and let dough rise until it doubles in size.	
Step 7	Punch dough down.	
Step 8	Let dough rest for 10 to 15 minutes; do not punch down the dough or knead it again.	
Step 9	Divide the dough in half.	
Step 10	Place half of the dough on a greased pizza pan, spreading the dough thinly and pinching the edge of the crust to the rim of the pan.	

Assignment Sheet 3

C. **Prepare toppings.**

Ingredients: Mozzarella cheese
Pepperoni
Mushrooms
Olives
Onions
Bell peppers

Directions:	**Process used:**
Step 1 Shred mozzarella cheese.	
Step 2 Slice pepperoni, mushrooms, and olives.	
Step 3 Dice onions and peppers.	

D. **Prepare pizza for baking and serving.**

Directions:	**Process used:**
Step 1 Spread the pizza sauce evenly over the dough; cover the sauce with an even layer of mozzarella cheese; add pepperoni and other toppings as desired.	
Note: Save any leftover sauce for dipping Italian bread sticks in; save the leftover toppings.	
Step 2 Bake the pizza for 20 to 25 minutes at 425 degrees F.	
Step 3 Remove the pizza from the oven when the cheese is melted and bubbly.	
Step 4 For soft, golden-brown crust, brush the edges of the pizza crust lightly with melted butter or margarine.	
Step 5 Slice and serve pizza.	

Assignment Sheet 3

Part B **Complete an operation-process chart and flow-process charts for a production process for manufacturing pizza.**

Activity checklist Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Read** Student Supplement 3, "Production-Process Planning," which begins on page 47.

_____ 2. **Sketch an operation-process chart:**

On a separate piece of paper, sketch an operation-process chart that will include each of the four operations listed in the recipe for making pizza you analyzed in Part A of this assignment sheet: (1) prepare pizza sauce, (2) prepare pizza crust, (3) prepare toppings, and (4) prepare pizza for baking and serving.

To complete the sketch, add all the needed chart symbols, connecting lines, and labels as illustrated in the operation-process chart in Figure 1 in Student Supplement 3.

_____ 3. **Complete flow-process charts:**

- Study the sample flow-process charts in Figures 2, 3, and 4 in Student Supplement 3.
- Make several copies of the blank flow-process chart on page 46.
- In pencil, fill out a flow-process chart for each of the four operations you outlined on the operation-process chart you sketched.

  In your flow-process charts, connect the symbols with a line, add task numbers, descriptions of the tasks, the date, totals (operations, inspections, etc.), and beginning and ending information as shown in the samples in Student Supplement 3.

_____ 4. **Turn in** your sketched operation-process chart and penciled-in flow-process charts to your instructor for evaluation.

_____ 5. Your instructor will return your charts with suggestions for improvement. **Make the improvements** your instructor suggests.

_____ 6. **Complete** a finished drawing of your improved operation-process chart, and complete finished copies of your flow-process charts.

Use a computer or a typewriter, or complete the charts in ink. Your charts will be judged on their neatness as well as on how complete and correct they are.

_____ 7. **Return** your completed charts to your instructor for **final evaluation**.

Assignment Sheet 3

Part C **Complete a plant-layout/product-flow diagram for manufacturing pizza.**

Activity checklist Put a checkmark on the blank before each activity below as you complete it.

_____ 1. **Study** the sample plant-layout/product-flow diagram in Figure 5 in Student Supplement 3.

_____ 2. **Complete a sketch for a plant layout/product-flow diagram:**

- Your instructor will provide you with grid paper to use in helping you draw your plant layout. Using the grid paper, make a to-scale floor-plan sketch of the laboratory area of your classroom. The sketch must show all the hookups for utilities (electricity, water, gas, air, etc.) that are located in the laboratory.

- Study the analysis you completed in Part A of this assignment and the charts you completed in Part B of this assignment, and then, decide which pieces of equipment would be needed in the production process you have designed.

  From pieces of cardboard, make to-scale templates (at the same scale you selected for your floor plan) of the equipment that would be needed in the production process you have designed.

- Place the equipment templates on the floor plan and arrange them so that the production process you design meets the key principles of production-process planning you studied in Student Supplement 3.

  You may have to arrange the equipment templates several times to achieve the best production process, so use some temporary method of placing the templates on the floor plan (removable tape, for example).

  Remember to plan aisles for the movement of people and materials in your plan.

- Draw flow-chart symbols, arrows, and lines to show the direction of product flow through the system. Use Figure 5 in Student Supplement 3 as an example.

_____ 3. **Turn in** your sketched plant-layout/product-flow diagram to your instructor for evaluation.

_____ 4. Your instructor will return your diagram with suggestions for improvement. **Make the improvements** your instructor suggests.

Assignment Sheet 3

_____ 5. **Complete a finished plant-layout/product-flow diagram** of your improved diagram.

Use a computer or complete the diagram in ink on grid paper. Your diagram will be judged on neatness as well as how complete and correct it is.

_____ 6. **Return** your completed diagram to your instructor for **final evaluation**.

BEST COPY AVAILABLE

Assignment Sheet 3

Flow-Process Chart

Product name _____ **Chart begins** _____

Part name _____ **Chart ends** _____

Part number ___ **Date** ___ / ___ / ___

○ Operations ___ ▷ Delays ___

□ Inspections ___ ▽ Storages ___

⇨ Transportations ___ Time ___

Symbols	Task no.	Description of task	Quantity	Distance (ft.)	Time (min.)	Machine required
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						
○⇨□▷▽						

100

Exploring Manufacturing Technology

Student Supplement 3—Production-Process Planning

Terms and definitions associated with production-process planning

- **Finished product**—The main product produced in a production process; a product that has been completely assembled and is ready for the consumer
- **By-product**—Product produced in addition to the main product produced in a production process
- **Assembly**—Process of combining the components of a product
- **Component**—A portion of a finished product; a portion that requires no further processing except assembly
- **Operation**—A series of specific tasks that produce one component of a finished product; also, the series of specific tasks that make up the job of one worker
- **Task**—One step in an operation
- **Production process**—A series of operations to produce a finished product

Key principles of production-process planning

1. Each worker does one job (completes one operation) in the production process.
2. Wasted time and motion are eliminated from each operation in the production process, resulting in an efficient overall production process.
3. Tools, equipment, and workers are placed in a logical order (sequence) to best complete the series of operations necessary to produce the finished product.

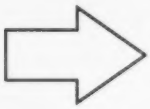
   Examples: Materials needed in an operation are brought to the worker in an efficient manner (materials-handling process).

   Distances that the components are moved from operation to operation in the production process are kept as short as possible.

Symbols used in the charts and diagrams created to analyze a production-process plan

Symbol/name	Description
Operation symbol	Symbol used to indicate an operation in a manufacturing process; designates a process in which a basic material has been modified or changed in its physical or chemical makeup by being separated, cast, formed, conditioned, assembled, or finished.

Student Supplement 3

Symbol/name	Description
Transportation symbol 	Symbol used to indicate a process in which a basic material, component, or the finished product is moved.
Inspection symbol	Symbol used to indicate a process in which a basic material, component, or the finished product is examined to check for quality.
Delay symbol	Symbol used to indicate a wait in the production process (a time when a basic material, component, or the finished product is held until ready for the next operation in the production process).
Storage symbol	Symbol used to indicate that a basic material, component, or the finished product is put in a protected location.

Types of charts and diagrams created to analyze a production-process plan

Many different charts and diagrams are drawn to show a logical sequence of the operations and the inspection, transportation, delay, and storage processes necessary to finish a particular product. Each of these charts and diagrams is analyzed, and then, the charts or diagrams that best demonstrate the key principles of production are selected to establish the best production process. The completed charts and diagrams provide an overview of the entire manufacturing process.

- **Operation-process chart**—A chart that shows a logical sequence of the operations, the inspections, and storage processes necessary to best complete a production process

  An operation-process chart shows the operations and inspections and storage processes in a production process, but it does **not** show transportations and delays.

  Figure 1 on page 50 shows an operation-process chart for manufacturing a two-component tic-tac-toe game.

- **Flow-process chart**—A chart that shows a logical sequence of the tasks to best complete one operation in a production process

Student Supplement 3

A flow-process chart shows the tasks and the transportations, inspections, delays, and storages necessary to complete one operation in a production process.

Figures 2, 3, and 4 on pages 51, 52, and 53 show three flow-process charts of the tasks necessary to complete the three operations in manufacturing the two-component tic-tac-toe game.

- **Plant-layout/product-flow diagram**—A diagram consisting of two parts: (1) a plant-layout floor plan and (2) a product-flow diagram

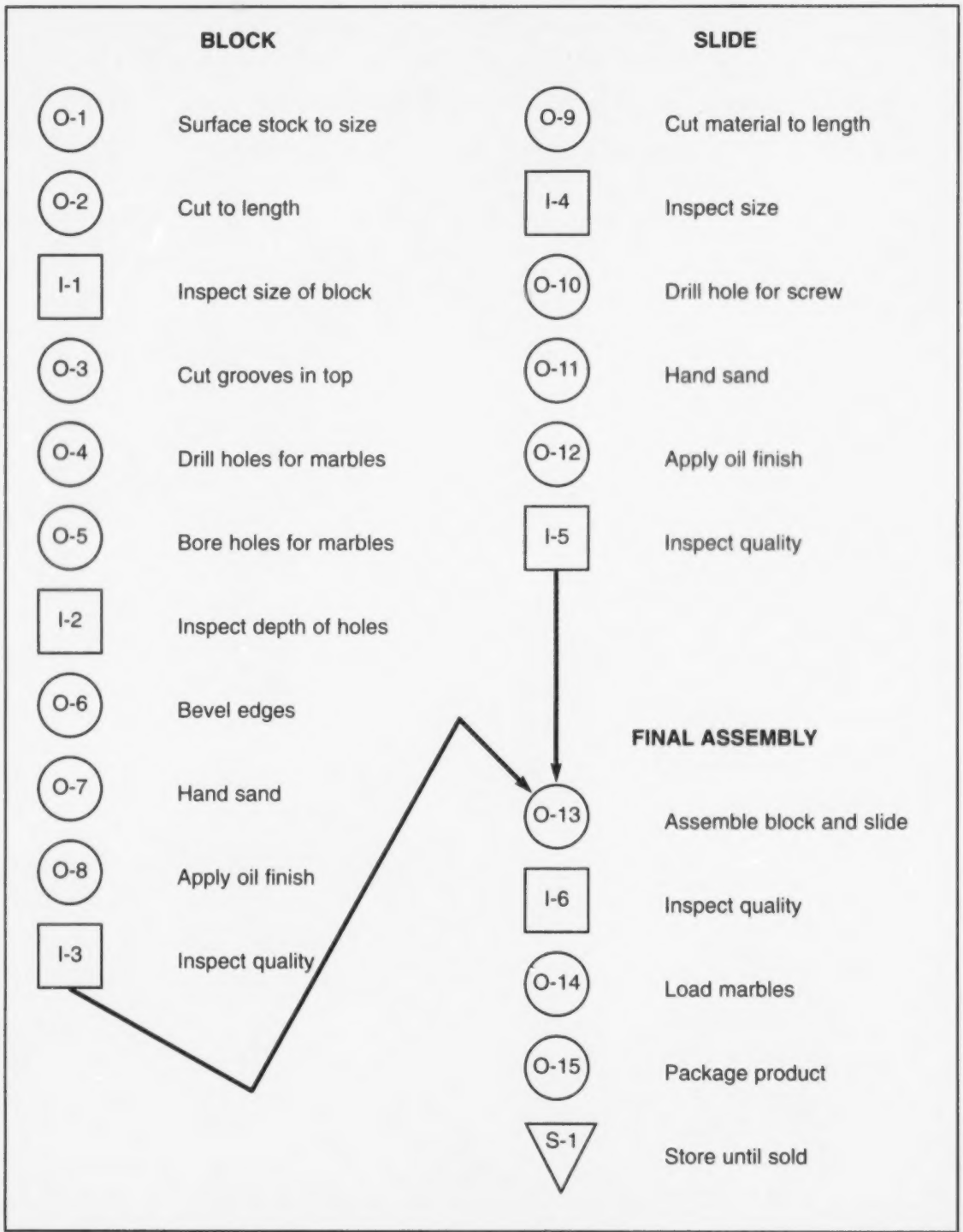
A **plant layout** is a to-scale floor-plan drawing of a plant facility, showing the location of utilities for hookups of electricity, water, gas, air, etc.; the location of the machines to be used in the production process; and the location of aisles for movement of people and materials.

A **product-flow diagram** is a series of symbols drawn on the plant-layout floor plan to show the movement of the product components as they are produced and moved from one work station to another in the production process to complete the finished product.

Figure 5 on page 54 is an example of a plant-layout/product-flow diagram for producing the two-component tic-tac-toe game.

Student Supplement 3

Figure 1: Operation-process chart to produce two-component tic-tac-toe game



Student Supplement 3

Flow-Process Charts to Produce Tic-Tac-Toe Game

Figure 2: Flow-process chart 1

Product name Tic-Tac-Toe
Part name Block
Part number 1 **Date** ____ / ____ / ____

Chart begins O-1
Chart ends T-7

○ Operations 8 ▢ Delays 1
□ Inspections 3 ▽ Storages 0
⇨ Transportations 7 Time ____

Symbols	Task no.	Description of task	Quantity	Distance (ft.)	Time (min.)	Machine required	Tooling required
○ ⇨ □ ▢ ▽	O-1	Surface stock to size				Planer	
○ ⇨ □ ▢ ▽	T-1	Transport to radial arm saw					
○ ⇨ □ ▢ ▽	O-2	Cut to length				Radial arm saw	Stop block
○ ⇨ □ ▢ ▽	I-1	Inspect size of block					Go/no-go gauge
○ ⇨ □ ▢ ▽	T-2	Transport to table saw					
○ ⇨ □ ▢ ▽	O-3	Cut grooves in top				Table saw	
○ ⇨ □ ▢ ▽	T-3	Transport to drill #1					
○ ⇨ □ ▢ ▽	O-4	Drill holes for marbles (twist bit)				Drill press	Jig #1
○ ⇨ □ ▢ ▽	T-4	Transport to drill press #2					
○ ⇨ □ ▢ ▽	O-5	Bore holes for marbles (spade bit)				Drill press	Jig #2
○ ⇨ □ ▢ ▽	I-2	Inspect depth of holes					Go/no-go gauge
○ ⇨ □ ▢ ▽	T-5	Transport to disc sander					
○ ⇨ □ ▢ ▽	O-6	Bevel edges				Disc sander	Fixture #1
○ ⇨ □ ▢ ▽	T-6	Transport to finishing table					
○ ⇨ □ ▢ ▽	O-7	Hand sand				Sand paper	
○ ⇨ □ ▢ ▽	O-8	Apply oil finish				Rags and finish	
○ ⇨ □ ▢ ▽	D-1	Allow finish to dry					
○ ⇨ □ ▢ ▽	I-3	Inspect quality					
○ ⇨ □ ▢ ▽	T-7	Transport to final assembly table					

Student Supplement 3

Flow-Process Charts to Produce Tic-Tac-Toe Game

Figure 3: Flow-process chart 2

Product name Tic-Tac-Toe **Chart begins** O-9

Part name Slide **Chart ends** T-10

Part number 2 **Date** ___ / ___ / ___

○ Operations 4 ▢ Delays 1

□ Inspections 2 ▽ Storages 0

⇨ Transportations 3 Time ___

Symbols	Task no.	Description of task	Quantity	Distance (ft.)	Time (min.)	Machine required	Tooling required
○ ⇨ □ ▢ ▽	O-9	Cut (presawn thickness and width) material to length				Band saw	Jig #3
○ ⇨ □ ▢ ▽	I-4	Inspect size					Go/no-go gauge
○ ⇨ □ ▢ ▽	T-8	Transport to work station #1					
○ ⇨ □ ▢ ▽	O-10	Drill hole for screw				Hand drill twist bit	Jig #4
○ ⇨ □ ▢ ▽	T-9	Transport to finishing table					
○ ⇨ □ ▢ ▽	O-11	Hand sand				Sand paper	
○ ⇨ □ ▢ ▽	O-12	Apply oil finish				Rags and finish	
○ ⇨ □ ▢ ▽	D-2	Allow finish to dry					
○ ⇨ □ ▢ ▽	I-5	Inspect quality					
○ ⇨ □ ▢ ▽	T-10	Transport to final assembly table					
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							
○ ⇨ □ ▢ ▽							

Student Supplement 3

Flow-Process Charts to Produce Tic-Tac-Toe Game

Figure 4: Flow-process chart 3

Product name Tic-Tac-Toe **Chart begins** O-13

Part name Final Assembly **Chart ends** S-1

Part number 1 & 2 **Date** ____ / ____ / ____

○ Operations 3 ▢ Delays 0

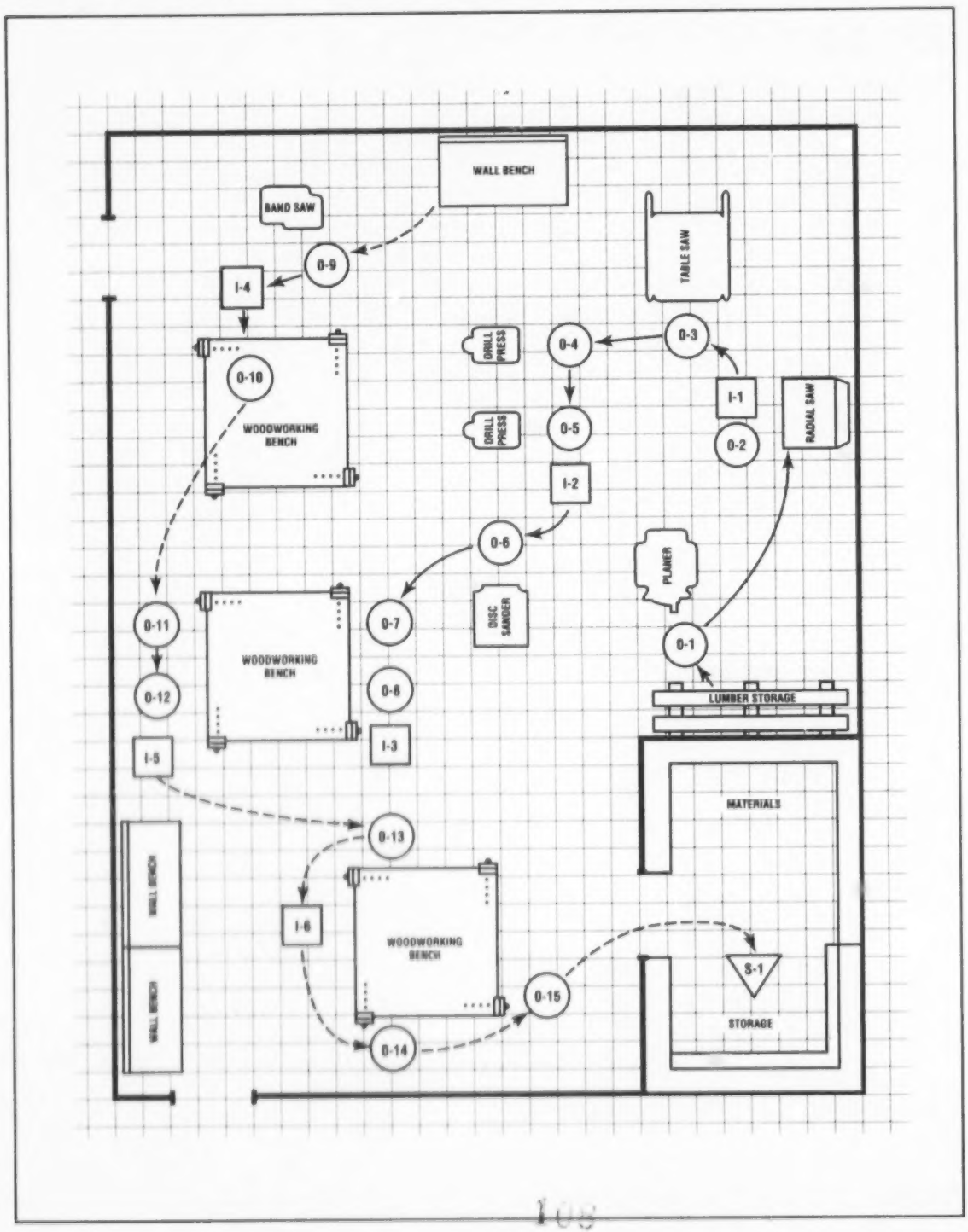
□ Inspections 1 ▽ Storages 1

⇨ Transportations 1 Time ____

Symbols	Task no.	Description of task	Quantity	Distance (ft.)	Time (min.)	Machine required	Tooling required
○⇨□▢▽	O-13	Assemble slide to block with decorative screw				Screw driver	
○⇨□▢▽	I-6	Inspect quality					
○⇨□▢▽	O-14	Load two sets of marbles					
○⇨□▢▽	O-15	Package product					
○⇨□▢▽	T-11	Transport to storage					
○⇨□▢▽	S-1	Store until sold					
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							
○⇨□▢▽							

Student Supplement 3

Figure 5: Plant-layout/product-flow diagram to produce two-component tic-tac-toe game



Exploring Manufacturing Technology

Lab Activity Sheet 1—Perform a Production-Process Evaluation Activity

Introduction

In this lab activity, you will assemble ball-point pens, using two different production processes. In the first part of the lab activity, you will work in a group to design and perfect a production process that will include all the group members as workers; in the second part of the lab activity, you will work alone to design and perfect a production process in which you are the only worker. Then, you will learn how to compare the productivity of the group's production process with the productivity of your individual production process.

Part A **Plan and evaluate a group production process.**

Equipment and materials

Your instructor will provide you with 200 ball-point pens.

Procedure

Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Your instructor will divide your class into groups with three people per group. With your group members, review the worksheet associated with this lab activity, which begins on page 59.

_____ 2. As a group, complete the pre-performance check for Procedure A (Part A) on the worksheet and receive your instructor's signed approval for the information you have listed for performing the group production process.

_____ 3. Review the evaluation criteria listed in the performance evaluation (Part L) on the worksheet.

_____ 4. Assemble pens:

- Assemble as many pens are possible for 10 minutes, following the production-process plan your group recorded in Part A on the worksheet.
- Your instructor will use a stop watch to time your group during this 10-minute period.

_____ 5. Evaluate your group's production process:

- In Part B on the worksheet, record the number of pens your group assembled in the first 10-minute period.
- Examine each of the assembled pens to see if they meet the quality standards called for in Part A on the worksheet. Then, in Part B on the worksheet, record the number of pens rejected because they did not meet the quality standards.

_____ 6. Disassemble the pens your group assembled in Step 4.

_____ 7. Participate in a discussion with your group members. Decide on ways to improve your group's production-process plan. Record the improvements to your production-process plan on Part C of the worksheet.

_____ 8. Assemble pens:

- Assemble as many pens as possible for 10 minutes, following the improved production-process plan your group recorded on Part C of the worksheet.
- Your instructor will use a stop watch to time your group during this 10-minute period.

_____ 9. Evaluate your group's improved production process:

- In Part D on the worksheet, record the number of pens your group assembled in the second 10-minute period.
- Examine each of the assembled pens to see if they meet the quality standards called for in Part A on the worksheet. In Part D on the worksheet, record the number of pens rejected because they did not meet the quality standards.

_____ 10. Participate in a discussion with your group members. Compare the two production-process plans and determine the reasons that one plan worked better than the other. Record the findings of your group in Part E on the worksheet.

Part B **Plan and evaluate an individual production process.**

Equipment and materials Your instructor will provide you with 100 ball-point pens.

Procedure Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Complete the pre-performance check (Part F) on the worksheet and receive your instructor's signed approval for the information you have listed for performing the individual production process.

_____ 2. Review the evaluation criteria listed in the performance evaluation (Part L) on the worksheet.

_____ 3. Assemble pens:

- Assemble as many pens as possible for 10 minutes, following the production-process plan you recorded in Part F on the worksheet.
- Your instructor or another class member will use a stop watch to time you during this 10-minute period.

Lab Activity Sheet 1

_____ 4. Evaluate your production process:

- In Part G on the worksheet, record the number of pens you assembled in the first 10-minute period.
- Examine each of the assembled pens to see if they meet the quality standards called for in Part A on the worksheet, record the number of pens rejected because they did not meet the quality standards.

_____ 5. Disassemble the pens you assembled in Step 3.

_____ 6. Review your production-process plan. Decide on ways to improve your production-process plan. Record the improvements to your production-process plan on Part H of the worksheet.

_____ 7. Assemble pens:

- Assemble as many pens as possible for 10 minutes, following the improved production-process plan you recorded in Part H on the worksheet.
- Your instructor or another class member will use a stop watch to time you during this 10-minute period.

_____ 8. Evaluate your production process:

- In Part I on the worksheet, record the number of pens you assembled in this second 10-minute period.
- Examine each of the assembled pens to see if they meet the quality standards called for in Part A on the worksheet. In Part I on the worksheet, record the number of pens rejected because they did not meet the quality standards.

_____ 9. Compare the two production-process plans and determine the reasons that one plan worked better than the other. Record your findings in Part J on the worksheet.

_____ 10. Return ball-point pens to your instructor or to proper storage, as your instructor directs.

Part C **Compare the productivity of the group production process and the individual production process.**

Procedure Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Complete the steps in Part K on the worksheet.

_____ 2. Turn in your completed worksheet to your instructor for evaluation.

_____ 3. Your instructor will return your worksheet with suggestions for improvement. Make the improvements your instructor suggests, and then, return your revised worksheet to your instructor for final evaluation.

Your instructor will rate your performance using the evaluation criteria listed in Part L on the worksheet.

Lab Activity Sheet 1

Worksheet—Perform a Production-Process Evaluation Activity

Name _____ Date _____

Part A: Pre-performance check for Procedure A, plan and evaluate a group production process

Complete the following information concerning your group's production process for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On a separate sheet(s) of paper, develop a step-by-step production process for assembling the ball-point pens. Analyze each step of the production process by identifying which method (separating, forming, casting or molding, conditioning, assembling, or finishing) would be used to complete that step.
- Complete an operation-process chart, flow-process charts, and a plant-layout/product flow diagram for your production process.
- Use the following criteria as the **quality standards** for judging the quality of the ball-point pens your group will assemble.
  - — Each "quality" ball-point pen must write smoothly.
  - — The components of each pen must fit together properly and any moving components must function smoothly.
  - — All of the original components for the ball-point pens must be used on each finished ball-point pen.

Instructor's signature _____

Part B: Post-production evaluation of the first 10-minute group production process

Record the results of your first 10-minute production-process group activity below.

- Number of ball-point pens assembled in the first 10-minute production-process group activity

  _____

- Number of ball-point pens rejected because they did not meet the quality standards given above

  _____

BEST COPY AVAILABLE

Lab Activity Sheet 1

Worksheet—Perform a Production-Process Evaluation Activity

Part C: Planned improvements to the group production process

Complete the following information concerning your group's plans for improving the production process for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On separate sheets of paper, correct your group's operation-process chart, flow-process charts, and plant-layout/product-flow diagram to reflect the improvements you have decided to make to improve your group production-process plan developed in Part A of this worksheet.

Instructor's signature _____

Part D: Post-production evaluation of the second 10-minute group production process

Record the results of your second 10-minute production-process group activity below.

- Number of ball-point pens assembled in the second 10-minute production-process group activity

  _____

- Number of ball-point pens rejected because they did not meet the quality standards given in Part A of this worksheet

  _____

Part E: Post-production comparison of the two 10-minute group production processes

Complete the following information concerning your group's production processes for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On a separate sheet(s) of paper, write a comparison of the two group production processes. In this comparison, state which production process worked better, and then, explain the reasons why that production process worked better.

Instructor's signature _____

Lab Activity Sheet 1

Worksheet—Perform a Production-Process Evaluation Activity

Part F: Pre-performance check for Procedure B, plan and evaluate an individual production process

Complete the following information concerning your individual production process for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On a separate sheet(s) of paper, develop a step-by-step production process for assembling the ball-point pens. Analyze each step of the production process by identifying which method (separating, forming, casting or molding, conditioning, assembling, or finishing) would be used to complete that step.
- Complete an operation-process chart, flow-process charts, and a plant-layout/product-flow diagram for your production process.
- Use the criteria in Part A of this worksheet as the quality standards for judging the quality of the ball-point pens you will assemble.

Instructor's signature _____

Part G: Post-production evaluation of the first 10-minute individual production process

Record the results of your first 10-minute production-process individual activity below.

- Number of ball-point pens assembled in the first 10-minute production-process individual activity

  _____

- Number of ball-point pens rejected because they did not meet the quality standards given in Part A of this worksheet

  _____

Part H: Planned improvements to the individual production process

Complete the following information concerning your individual plans for improving the production process for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On separate sheets of paper, correct your individual operation-process chart, flow-process charts, and plant-layout/product-flow diagram to reflect the improvements you have decided to make to improve your individual production-process plan developed in Part F of this worksheet.

Instructor's signature _____

Lab Activity Sheet 1

Worksheet—Perform a Production-Process Evaluation Activity

Part I: Post-production evaluation of the second 10-minute individual production process

Record the results of your second 10-minute production-process individual activity below.

- Number of ball-point pens assembled in the second 10-minute production-process individual activity

  _____

- Number of ball-point pens rejected because they did not meet the quality standards given in Part A of this worksheet

  _____

Part J: Post-production comparison of the two 10-minute individual production processes

Complete the following information concerning your production processes for assembling ball-point pens, and then, have your instructor sign on the blank line below.

- On a separate sheet(s) of paper, write a comparison of the two individual production processes. In this comparison, state which production process worked better, and then, explain the reasons why that production process worked better.

Instructor's signature _____

Part K: Comparison of productivity of group and individual production processes

Complete the following information, and then, have your instructor sign on the blank line on the next page.

- On the blank line below, record the higher number of pens assembled in one of the two 10-minute group production processes.

  Number of pens _____

- Use the following formula to calculate the total work hours completed in a 10-minute group production process, and then, record the number of work hours completed on the blank line provided below. Calculate your answers at each step to the nearest hundredth.

  10 minutes x 60 = Total seconds worked in 10 minutes.

  Total seconds worked in 10 minutes x Number of people in group = Total work seconds.

  Total work seconds ÷ 3600 = Total work hours

  Total work hours for your group = _____

Lab Activity Sheet 1

Worksheet—Perform a Production-Process Evaluation Activity

- On the blank line below, record the higher number of pens assembled in one of the two 10-minute individual production processes.

  Number of pens _____

- Use the following formula to calculate the total work hours completed in a 10-minute individual production process, and then, record the number of work hours completed on the blank line provided below. Calculate your answers to the nearest hundredth.

  10 minutes x 60 = Total seconds worked in 10 minutes.

  Total work seconds ÷ 3600 = Total work hours

  Total work hours = _____

- On a separate piece of paper, record conclusions you can draw about the productivity of the group and individual production processes by doing the calculations required above.

Instructor's signature _____

Part L: Performance evaluation

Evaluation criteria	**Rating**
Student took an active part in the group production process planning activity.	_____
Completed charts and diagrams for the production processes meet the criteria of the key principles of production-process planning.	_____
Completed charts and diagrams are neat, complete, and accurate.	_____
Calculations made in the evaluation activity are accurate.	_____
Conclusions recorded in the evaluation activity are logical and accurate.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

Exploring Manufacturing Technology

Lab Activity Sheet 2—Fabricate and Test Composite Materials

Introduction

The purpose of this lab activity sheet is to demonstrate the greater strength-to-weight ratios possible when comparing components manufactured from solid materials to components manufactured from composite materials.

In Part A of this lab activity, you will fabricate three composite materials. Although you will not be creating exotic composite materials—you will be using balsa, posterboard, and paper sheets to create laminate composites—the strength-to-weight design characteristics associated with composites can be demonstrated with these common materials.

In Part B, you will construct four small-scale wing spars (see Student Supplement 4)—three spars made from the composite materials you fabricated in Part A and one from solid wood. Then, you will test the strength-to-weight ratios of these four wing spars by placing each spar into a device called an *attachment point* and adding weights to the end of the spar until the spar fails. Next, you will calculate the strength-to-weight ratio of each wing spar and determine which of the materials used is the strongest yet lightest.

Part A **Fabricate composite materials.**

Equipment and materials

- Desk or other flat work surface
- Newspaper or other large sheets of scrap paper
- Boards and C-clamps
- Balsa-wood sheet material
- Posterboard strips
- Paper strips
- Glues (white glue and wood glue)
- Pencil
- Ruler
- Scissors

Procedure

Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Read Student Supplement 4, "Composite Materials Used in Airframe Manufacturing," which begins on page 77.

_____ 2. Your instructor will divide your class into groups of two. With your group member, review the worksheet associated with this lab activity, which begins on page 73.

_____ 3. Review the evaluation criteria listed in the performance evaluation (Part D) on the worksheet.

_____ 4. Study the wing-spar pattern in Student Supplement 5 on page 83 to determine the specified dimensions for the finished wing spar.

Lab Activity Sheet 2

_____ 5. Determine the required dimensions of fabricated laminate needed to meet the specified dimensions for the finished wing spar.

Note: Be sure to allow enough area on the finished fabricated materials so that the wing-spar pattern in Student Supplement 5 can be easily transferred onto the fabricated laminate composite.

_____ 6. Complete the pre-performance check for Procedure A (Part A) on the worksheet and receive your instructor's signed approval for the information you have listed for performing the procedure.

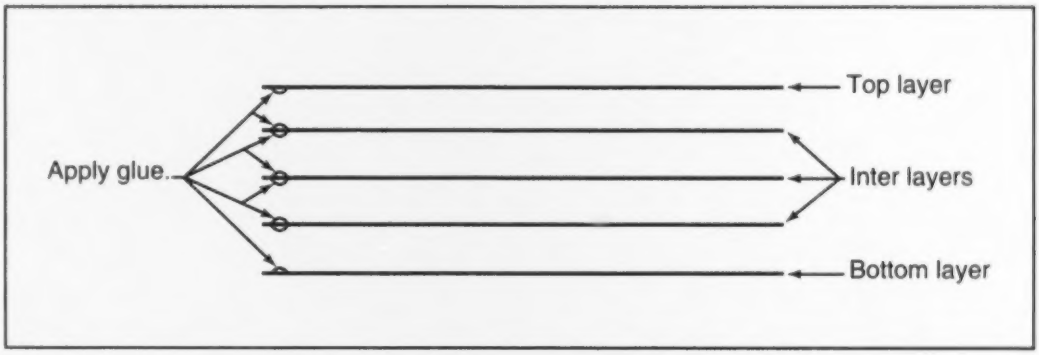
_____ 7. Spread scrap paper over the work surface to protect it from glue.

_____ 8. **Fabricate the balsa laminate composite:**

- Estimate and select the quantities of balsa needed to meet the dimensions determined in Step 6.
- Study the gluing pattern in Figure 1 below.

Note: Gluing the layers together in the following pattern—with glue on both sides of most of the sheet material—will make the laminate composite stronger.

Figure 1: Gluing pattern



- Following the gluing pattern, spread wood glue evenly over the surfaces of the balsa sheets, bonding layers until the materials meet the required dimensions determined in Step 6.
- Place the balsa laminate composite between two boards and secure with C-clamps to prevent warping; allow the composite to dry.

Lab Activity Sheet 2

_____ 9. **Fabricate the posterboard laminate composite:**

- Estimate and select the quantities of posterboard needed to meet the dimensions determined in Step 6.
- Following the gluing pattern in Figure 1 above, spread white glue evenly over the surfaces of the posterboard strips, forming layers until the materials meet the required dimensions determined in Step 6.
- Place the posterboard laminate composite between two boards and secure with C-clamps to prevent warping; allow the composite to dry.

_____ 10. **Fabricate the paper laminate composite:**

- Estimate and select the quantities of paper needed to meet the dimensions determined in Step 6.
- Thin the white glue to a watery consistency.
- Following the gluing pattern in Figure 1 above, use a paint brush to spread the white glue evenly over the surfaces of the paper strips, forming layers until the layered materials meet the required dimensions determined in Step 6.
- Place the paper laminate composite between two boards and secure with C-clamps to prevent warping; allow the composite to dry.

  Note: The paper laminate composite material will take longer to dry than the balsa or posterboard material.

Part B **Construct and test wing spars.**

Equipment and materials

- Balsa, posterboard, and paper laminate composite materials fabricated in Part A
- Piece of solid wood provided by your instructor
- Wing-spar pattern you created in Part A
- Pencil
- Ruler
- Carbon paper
- Posterboard
- Narrow-bladed handsaw such as a coping saw or keyhole saw
- Scissors
- X-acto knife
- Eye protection
- Sandpaper
- File
- Attachment point provided by your instructor
- Table or workbench
- C-clamp
- Protractor

BEST COPY AVAILABLE

Lab Activity Sheet 2

- Two-foot length of 20- to 30-pound-test fishing line
- Drill and drill bit
- Scale
- Weight hanger and weights
- Ceiling hooks and pulleys

Procedure Put a checkmark on the blank line before each step below as you complete it.

_____ 1. Create posterboard wing-spar pattern:

- Locate the paper wing-spar pattern you created in Part A.
- Using the pencil, ruler, and carbon paper, transfer the spar pattern onto the posterboard.

  Note: It is important that the transfer pattern be as accurate as possible.

- Using scissors, rough-cut around the posterboard pattern piece.
- Using an X-acto knife, trim the posterboard pattern piece to exact dimensions.

_____ 2. Transfer the wing-spar pattern onto the **solid-wood** and the **laminate** composite materials:

- Place the posterboard pattern on the top surface of each material and secure in place.
- Using a pencil, carefully trace around the posterboard pattern.

_____ 3. Form the wing spars from the **solid-wood** and the **laminate** composite materials:

- Rough-cut around the pencil marks, using the scissors and the X-acto knife for the posterboard and the paper laminate composite materials and the narrow-bladed saw for the balsa laminate composite and the solid-wood materials.
- File and/or sand the materials to remove excess material and to shape the wing spars to the exact dimensions.

_____ 4. Prepare each wing spar for testing:

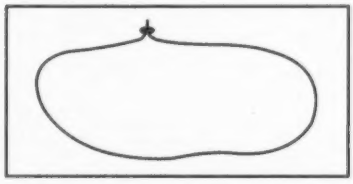
- Consult the wing-spar pattern to determine the proper placement for the $\frac{7}{64}$-inch hole; mark the hole location on the wing spar.
- Drill the $\frac{7}{64}$-inch hole on the wing spar.

Lab Activity Sheet 2

- Attach the fishing line to the hole on the wing spar:

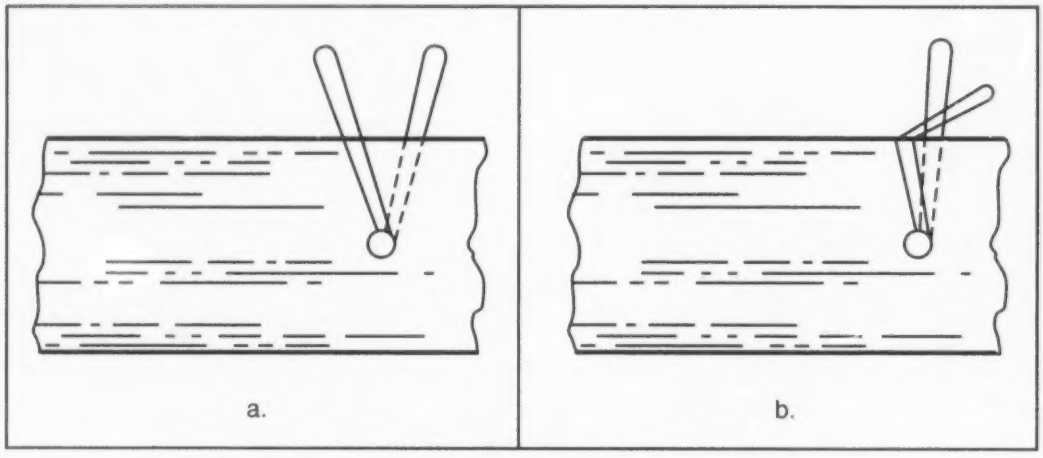
  — Tie the ends of the fishing line together to form a loop as shown in Figure 2 below.

Figure 2



  — Slide the loop through the hole on the wing spar and then slip one end of the loop through the other as shown in Figure 3.

Figure 3



_____ 5. Construct the pulley system:

- Study the diagram in Figure 4 on the next page.
- Clamp the attachment point to the table or workbench as shown in Figure 4.
- Attach hooks and pulleys to the ceiling as shown in Figure 4.
- Determine the amount of fishing line needed for the pulley system.

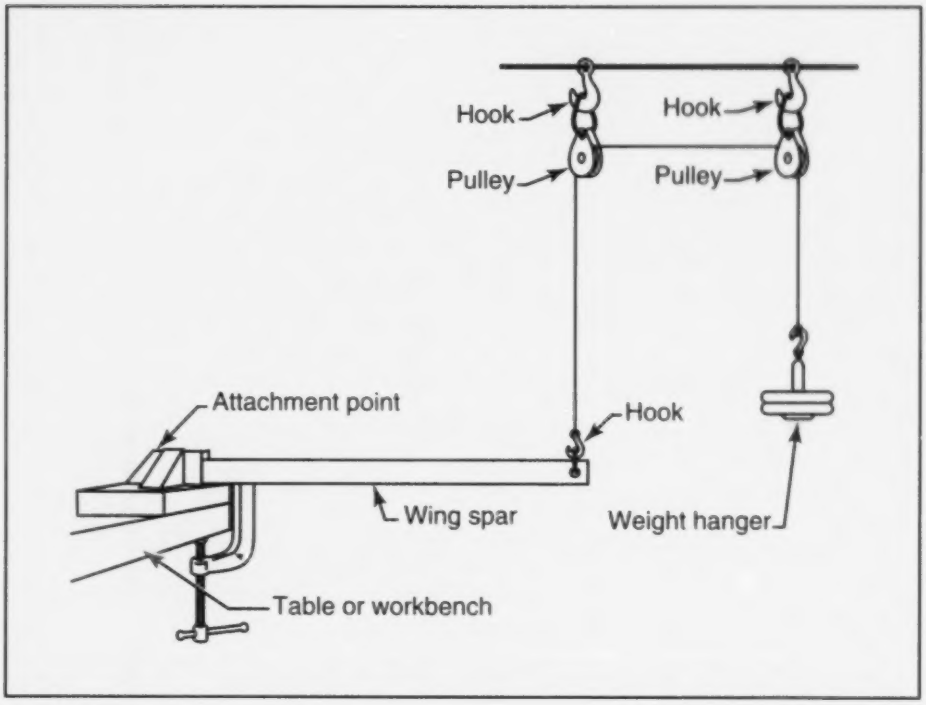
  Note: The amount of fishing line required will vary depending on the height of the ceiling in the lab, the height of the table or workbench, and the distance between the pulleys.

- Weigh the fishing line, the hook to be placed at the end of the fishing line (see Figure 4), and the weight hanger; record on Part B of the worksheet.
- String the fishing line through the pulley system.
- Make a loop at each end of the fishing line.
- Attach the hook to the loop at the end of the fishing line over the table or the workbench (see Figure 4).

  Note: This hook will be attached to the wing-spar loop that was constructed in Step 4 (see Figure 4).

- Attach the weight hanger to the loop at the other end of the fishing line (see Figure 4).

Figure 4



- Have your instructor okay the pulley-system setup by signing on the signature line in Part C of the worksheet.

_____ 6. Test a wing spar:

- Make four copies of Part B of the worksheet.
- On one copy of Part B of the worksheet, record the wing-spar material type being tested.

Lab Activity Sheet 2

- Weigh the wing spar and record the spar weight in Part B of the worksheet.
- Insert the fuselage end of the wing spar into the attachment point (see Figure 4).
- Attach the hook on the pulley system to the loop on the wing spar (see Figure 4).
- Level the wing spar.
- Place a protractor on the base of the attachment point and measure to the bottom edge of the wing spar to determine the beginning wing-spar angle; record the beginning wing-spar angle in Part B of the worksheet.

  Note: The beginning wing-spar angle will be used as a reference point for determining wing-spar failure. When the wing spar has been stressed to a point 15 degrees beyond the beginning angle, the wing spar will be considered to have failed.

- Attach the weight hanger to the fishing-line loop and begin adding weights in small increments (ounces).
- Periodically remove the weight hanger and weights and measure the wing-spar angle.
- Continue until the wing-spar angle measures 15 degrees beyond the beginning wing-spar angle.
- On Part B of the worksheet, calculate the combined weight of the weights added to the hanger when wing-spar failure occurs; record the combined weight.
- On Part B of the worksheet, calculate the strength-to-weight ratio of the wing spar and record the ratio.

_____ 7. Report the test results to your instructor.

_____ 8. Repeat Steps 6 and 7 until all the wing spars have been tested.

_____ 9. Turn in your completed worksheet to your instructor for evaluation.

_____ 10. Your instructor will return your worksheet with suggestions for improvement. Make the improvements your instructor suggests, and then, return your revised worksheet to your instructor for final evaluation.

_____ 11. Clean the work area and return equipment and materials to proper storage. Your instructor will rate your performance using the evaluation criteria listed in Part D on the worksheet.

Lab Activity Sheet 2

Worksheet—Fabricate and Test Composite Materials

Name _____ Date _____

Part A: Pre-performance check for Procedure A, fabricate composite materials

Complete the following information concerning the specified dimensions for the finished wing spar and the fabricated laminate needed to meet the specified dimensions for the finished wing spar, and then have your instructor sign on the blank line below.

- Study the reduced-scale pattern of the wing spar presented in Student Supplement 5. On a separate sheet of paper, draw a full-scale pattern for the wing spar.
- In the space below, compute the required dimensions of the fabricated laminate needed to meet the specified dimensions for the finished wing spar.

Instructor's signature _____

Lab Activity Sheet 2

Worksheet—Fabricate and Test Composite Materials

Part B: **Make at least four copies of this portion of the worksheet to be used in recording the results of the four tests you will complete in Lab Activity Sheet 2.**

1. Wing-spar material being tested _____

2. Combined weight of hook, line, and weight hanger _____

   Weight of wing spar _____

3. Beginning wing-spar angle _____

4. On a separate sheet of paper, calculate the combined weight of the weights added to the hanger. Record your answer on the blank provided.

   Combined weight of added weights _____

5. On a separate sheet of paper, calculate the strength-to-weight ratio of the spar tested, using the formula below. Record your answer on the blank provided.

   Strength-to-weight ratio _____

   $$\text{Strength of Spar} = \text{Weight of Hanger} + \text{Added Weight}$$

   $$\text{Strength-to-Weight Ratio} = \frac{\text{Strength of Spar}}{\text{Weight of Spar}}$$

   For example, if you determine that the weight of a wing spar is 150 pounds, the weight of the hanger is 150 pounds, and the combined weight of the added weights is 1000 pounds, you would calculate the strength-to-weight ratio of the spar as follows.

   $$\text{Strength of Spar} = 150 \text{ lb} + 1000 \text{ lb} = 1150 \text{ lb}$$

   $$\text{Strength-to-Weight Ratio} = \frac{1150 \text{ lb}}{150 \text{ lb}} = 7.67$$

Lab Activity Sheet 2

Worksheet—Fabricate and Test Composite Materials

Part C: Instructor's approval of pulley-system setup

- Instructor's signature below verifies that the pulley-system setup has been set up correctly and safely and the student may proceed with the test activity.

Instructor's signature _____

Part D: Performance evaluation

Evaluation criteria	Rating
Procedure was completed correctly and accurately.	_____
Procedure was completed safely.	_____
Worksheet was completed correctly and accurately.	_____
Clean-up and follow-up actions were adequate.	_____
Overall rating	_____

Evaluator's comments _____

_____

_____

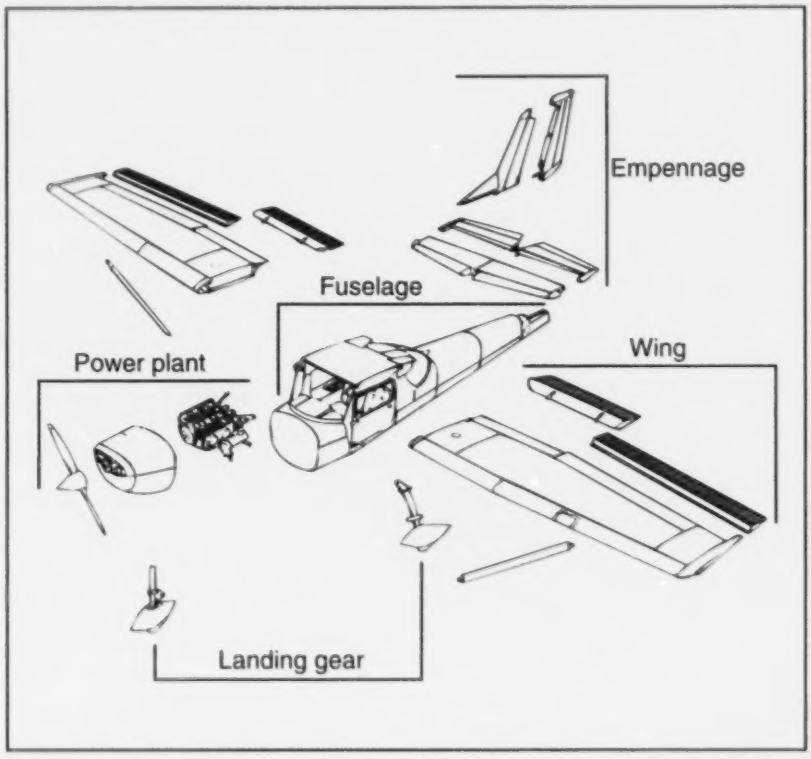
Exploring Manufacturing Technology

Student Supplement 4—Composite Materials Used in Airframe Manufacturing

Terms and definitions

- **Airframe**—Structure of an aircraft without the power plant (see Figure 1)

Figure 1: Airframe and power plant

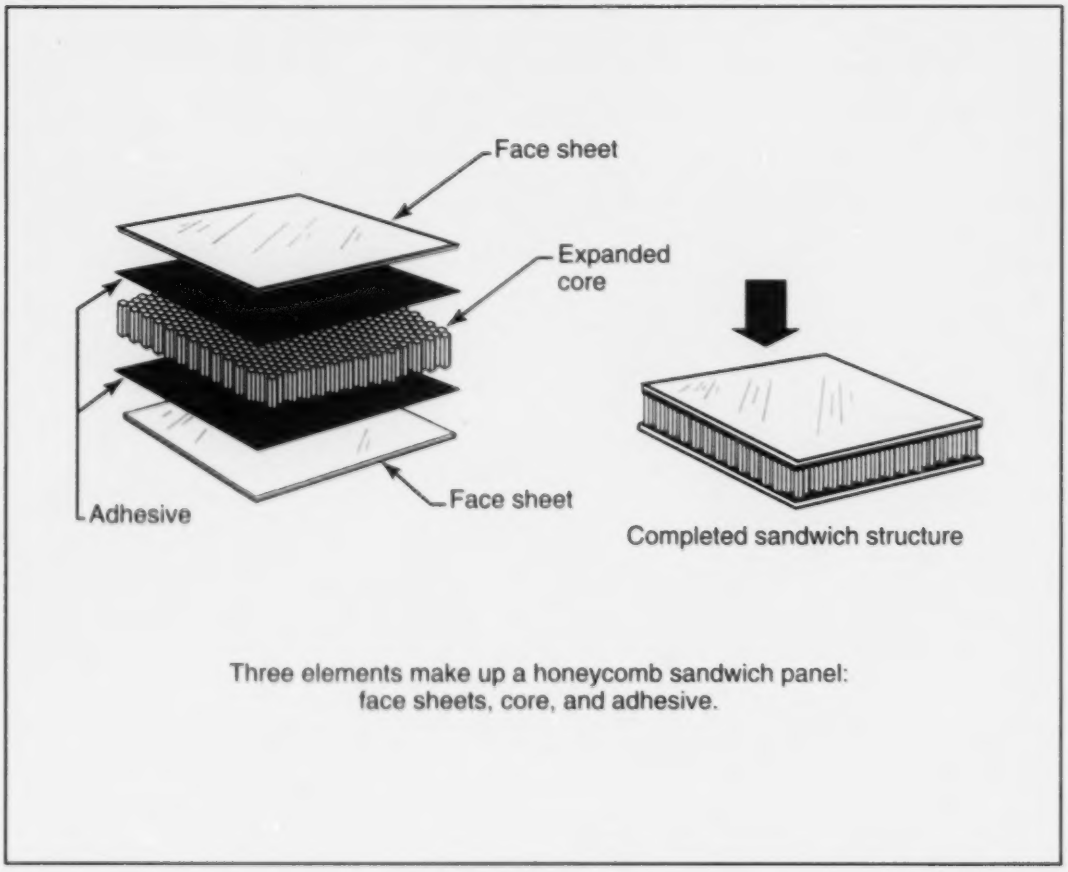


- **Power plant**—Engine and related parts that supply the power needed for forward motion in a self-propelled aircraft (see Figure 1)
- **Aramid**—Any of a group of synthetic materials fashioned into fibers, filaments, or sheets and used especially in textiles and plastics
- **Graphite**—Soft, black, lustrous carbon

  Note: Graphite is the material used in lead pencils.
- **Matrix**—Material in which something is enclosed or embedded
- **Epoxy resin**—Flexible, usually heat-set, resin used chiefly in coatings and adhesives
- **Polyimide resin**—Strong resin developed to withstand extremely high temperatures

- **Bonding**—Permanent assembly method in which two or more materials are combined using pressure, heat, or glue or some other bonding agent
- **Cohesive bonding**—Process of permanently fusing two or more like materials by melting or softening the materials through the use of heat, pressure, or a solvent
- **Adhesive bonding**—Process of using glue or cement to adhere the surfaces of two or more like or unlike materials
- **Aluminum-honeycomb laminate composites**—Layers of materials that are adhesive-bonded to form sandwich-type panels (see Figure 2)

Figure 2: Elements of a honeycomb sandwich panel

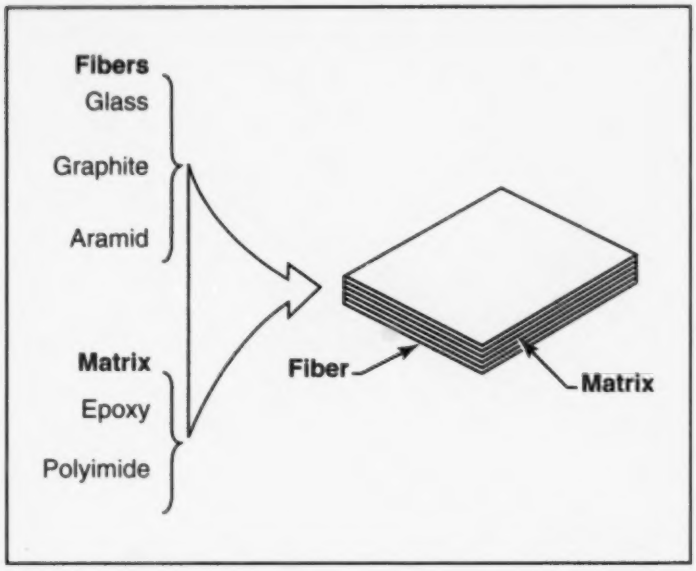


Three elements make up a honeycomb sandwich panel: face sheets, core, and adhesive.

- **Advanced fiber composites**—Complex materials in which graphite, glass, or aramid fibers are arranged in a matrix—generally epoxy or polyimide resin—and then heated under pressure to form a cohesively bonded substance that is strong but light and has a great resistance to corrosion and fatigue (see Figure 3)

Student Supplement 4

Figure 3: Elements of an advanced fiber composite material



Introduction to airframe manufacturing

Traditionally, the development of improvements in airframe design has been more of a gradual evolution than the result of a few important breakthroughs in design concepts or materials used in airframe components. One reason for this gradual evolution is that airframe designers have selected air frame materials for very practical reasons, and they have been hesitant to deviate from the use of these materials once selected.

The earliest airframes were wood-and-fabric structures. Designers selected wood as the material of choice for these early airframe designs because workers who would manufacture the structures were familiar with wood and its characteristics and because wood was plentiful, strong, and light enough to suit their designs, even though it was flammable and susceptible to rot.

Designers were content to stay with wood airframes until World War I and World War II, when airplanes began to be used in combat and the flammability and short service life of wood airframes became a problem. When designers were forced to look for other materials to use for airframe components, aluminum alloys became their material of choice, and in selecting aluminum alloys, designers were again very practical. The technology for manufacturing aluminum alloy had been developed so that the material was relatively cheap. Also, aluminum was light for its strength and nonflammable—even though heavier than wood and subject to corrosion and fatigue that limited its service life.

From World War II until 1973, designers continued to rely on solid aluminum or metal laminate composites fabricated from aluminum honeycomb. However, with the energy crisis of 1973, consideration of total energy consumption, both in manufacturing an aircraft and in its operation and maintenance, prompted designers to look for lighter, more corrosion- and fatigue-free material to use in their airframe designs.

Student Supplement 4

In response to a request of the U.S. Senate in 1975, NASA established the Aircraft Energy Efficiency (ACEE) program to develop fuel-saving technologies for both existing and future aircraft. The ACEE, in return, developed the following major technology programs to explore ways to improve both power-plant and airframe performance:

- More efficient wings and propellers.
- New and advanced composite materials for airframes that are lighter and more economical than metal.
- Ways to make today's jet engine more fuel efficient.
- New engine technologies for energy-saving aircraft of the future.

In the area of advanced composite materials for airframes, the ACEE, working with Boeing, McDonnell-Douglas, and Lockheed on cost-shared contracts, developed fiber composites and evauated these new materials in terms of performance and manufacturing costs. These evaluations led the ACEE to conclude that advanced fiber composites could replace metals in airframe designs because of their improved ability to sustain combat damage; greater resistance to corrosion and fatigue, which extends their service life and decreases total costs; and their improved strength-to-weight ratios, which result in fuel-cost savings.

What are advanced fiber composite materials?

Advanced fiber composites are complex materials in which two or more fibers are arranged in a matrix (generally epoxy or polyimide resin) and then heated under pressure to form a strong but light substance with great resistance to corrosion and fatigue.

The fibers most often used in these advanced composite materials are aramid, glass, and graphite. These materials arrive at the fabricator in various forms, including unidirectional fiber or board goods, tape, and woven cloth. Then, fabrication of the composite structures takes several forms. Tubular structures, large cylindrical tanks, and the like are made by winding fibers onto a mold while applying the resin matrix. Sheet-like structures are made by laying-up layers of fibers in molds. Curved structures are molded, and smaller structures like ribs and brackets are stamped or molded. But however the structure is fabricated, the resin-fiber mass finally is heated under pressure to cure it, and if fabricated and cured properly, an extremely strong, lightweight material results.

Although aluminum-honeycomb laminate composites continue to be used in airframe designs, designers are using the new advanced fiber composite materials more and more, and it is predicted that advanced fiber composites will become their material of choice.

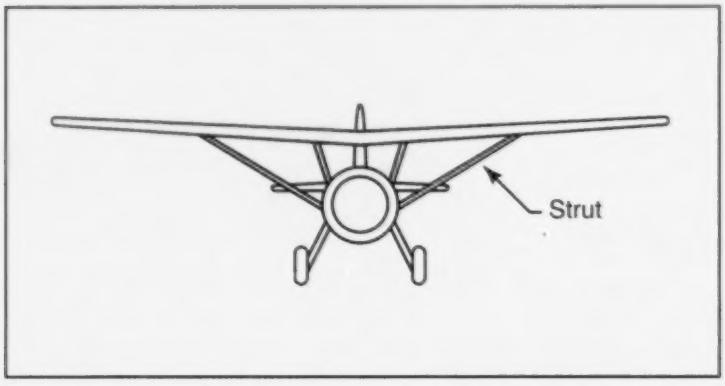
Constructing wing spars

Airframe designers are faced with three major problems in creating aircraft wing designs. When an airplane moves through the air during flight, the wings become the major load-bearing members of the airframe. Therefore, the designer must develop extremely strong wings to withstand the loads. Although wings must be strong, the designer must also make them light enough to minimize the downward force of gravity (weight), and their overall design clean-lined enough to reduce the backward force (drag) as the craft moves through the air. Three criteria an airframe designer must keep in mind, then, are strength, clean lines, and light weight.

Student Supplement 4

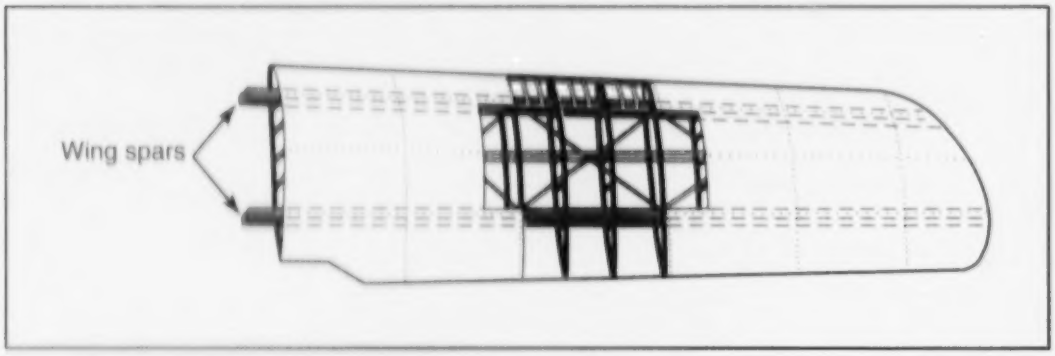
Early airframe designers used fabric-covered wood for wing structural components because of wood's light weight. However, these light, fabric-covered wood structures proved not to be strong enough, so designers added external braces called *wing struts* to strengthen the wing structure (see Figure 4). While strengthening the wing structure, struts interfered with the clean lines of the design and created drag.

Figure 4: Externally braced wing



To create a more clean-lined design, designers eventually developed an internally supported wing structure called a *cantilever wing. Cantilever* is an engineering term for a projecting beam that is rigidly fixed at one end. A cantilever wing is a wing design that contains one or two projecting beams that have one end fixed at the fuselage and the outer end free to move up and down to accommodate variations in the loads placed on the wing (see Figure 5). The projecting beams used in a cantilever wing are called *wing spars.*

Figure 5: Internally supported wing



Testing of manufactured materials

The testing of manufactured materials concerns studying a material under specified conditions in order to know how the material will perform in actual use. Standardized testing procedures for various materials have been developed by the American Society for Testing and Materials (ASTM), and other professional organizations. Two types of testing procedures are used: (1) destructive and (2) nondestructive.

Student Supplement 4

Destructive testing involves tests in which the test specimen is damaged so that it cannot be used again. Destructive testing is usually done to test the mechanical properties of the materials. Some common destructive tests are listed below.

- **Tensile testing**—Testing in which pulling forces are applied to the material to be tested

  For example, ropes and cables are tested for tensile strength in a tensile-testing machine.

- **Compression testing**—Testing in which pushing forces are applied to a material

  The walls of buildings need to have compression strength. A universal testing machine is used to measure the compression strength of the materials to be used in a wall.

- **Bend testing**—Testing to see how much force can be applied in one direction to a material until the material breaks

  The stiffness of a material and the quality of welded joints are bend-tested.

- **Impact testing**—Testing in which sudden forces are applied to test the toughness of a material

- **Hardness testing**—Testing in which forces are applied to test the ability of a material to resist indentation (denting), abrasion (scratching), and wear (rubbing)

- **Fatigue testing**—Testing in which a material is subjected to repeated changes in load to measure the endurance of the material

  For example, the hinge life of a one-piece plastic hinge can be determined by fatigue testing the plastic.

Nondestructive testing involves tests that do not damage the test material. Nondestructive testing is usually associated with inspections. Some common nondestructive tests are listed below.

- **Visual inspection**—Inspecting a material for surface defects such as cracks and porosity

- **Radiographic testing**—Exposing a material to some form of radiography (such as X-ray or gamma ray) to detect surface and subsurface defects

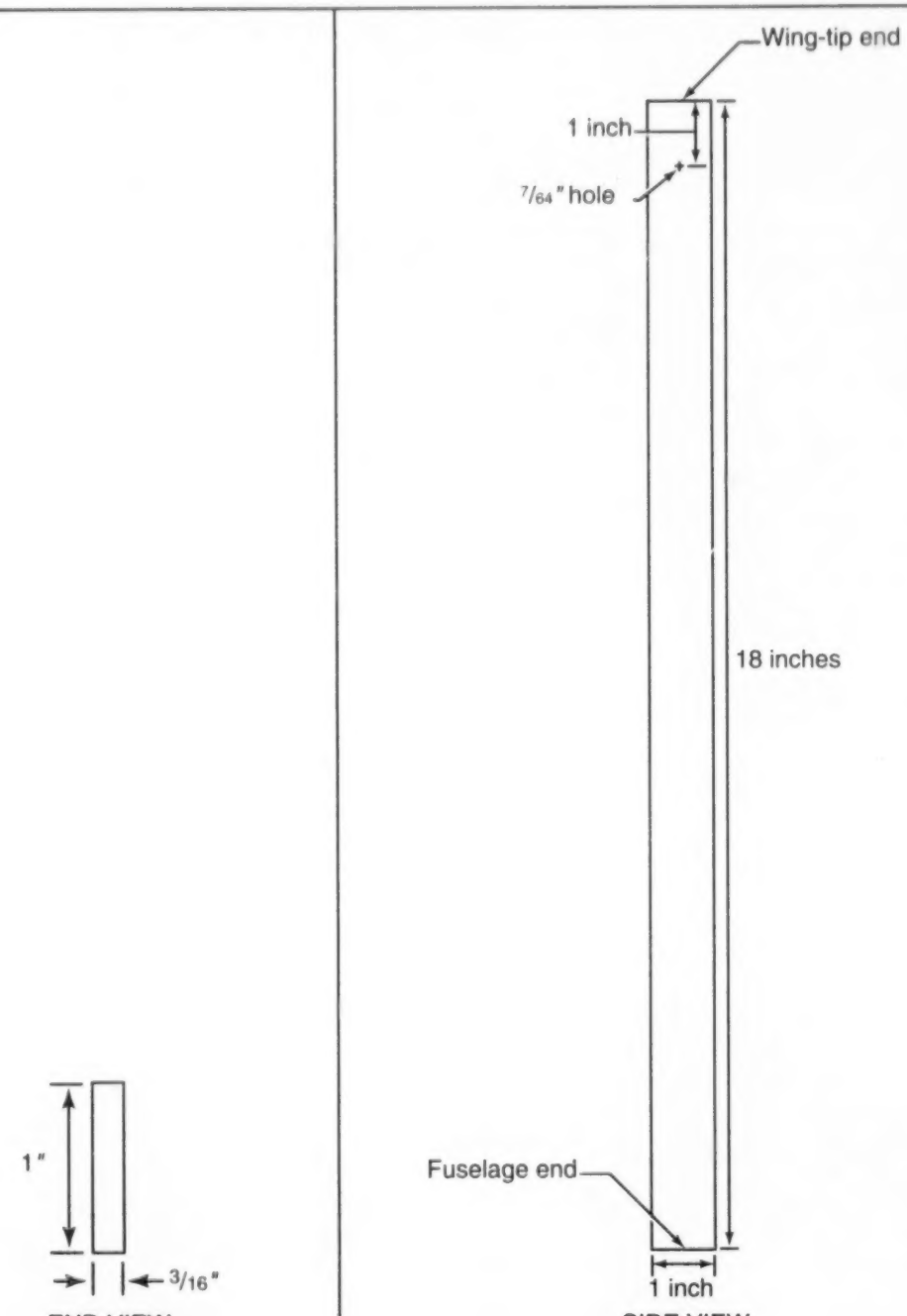
- **Ultrasonic testing**—Causing sound waves to travel through a material; interruptions in the sound waves indicate defects in the material

- **Magnetic testing**—Magnetizing the material to be tested and then applying iron particles to the surface of the material; iron particles collecting at breaks in the magnetic field of the magnetized material indicate a defect in the material at that location

- **Electrical testing**—Causing an electrical current to flow through a material; disruptions in the flow of current signal defects in the material

Exploring Manufacturing Technology

Student Supplement 5—Wing-Spar Pattern



Drawing is at full scale.

Drawing is at a reduced scale of 7/64" = 1".